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MENTAL AND PHYSICAL DEVELOPMENT

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Mental and Physical Development

Literature reviewed to August 1938

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with the cooperation of:

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INTRODUCTION

THE TOPICS of physical, motor, and mental development, and of interrelationships in mental and physical growth, have been considered in two previous numbers of the *Review of Educational Research* (April 1933 and February 1936). The material in the present number consists for the most part of a review of investigations published between July 1935 and July 1938. In some instances, reference has been made to earlier studies which were not included in previous reviews, or which have a particularly close relation to current work.

In keeping with the purpose and scope of this review, the summary has been directed primarily toward studies of normal samples of preschool and school children, and toward studies conducted in this country. Selective reference has been made, however, to the foreign literature wherever this has provided useful comparison from the point of view of methods or of results; in the case of mental development, particularly, the problem of environmental influence is one which requires the detailed consideration of results in different cultural situations.

With the broadening of fields of research and the quantitative increase of study in each field, the Committee has found unusual difficulty in staying within its space allotment; it may be necessary and also desirable in the future to abandon a systematic survey of current research, and to substitute a more critical summary and interpretation based on outstanding studies.

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HAROLD E. JONES, *Chairman*
Committee on Mental and Physical Development

CHAPTER I

The Development of Motor Functions and Mental Abilities in Infancy[1]

PSYCHE CATTELL

Reviews of the Literature

THE PRESENT REVIEW follows similar summaries in the *Review of Educational Research* for February 1936 and for April 1933. Valentine and Dockeray (83) summarized the literature from 1926 to 1936 dealing with experimental studies of the newborn. Dewey's survey (26) of behavior development in infants covered the period 1920-1934. Wenger and Williams (84) reviewed studies of learning in infants and preschool children.

Fetal Responses

Sontag and Wallace (81) found that activity in the fetus can be stimulated as early as the tenth week before birth. The method used was to place a small wooden disc in contact with the mother's abdomen, and directly over the fetal head; a door bell buzzer was then vibrated against the disc. The movement of fetal muscles in response to the stimulus became more marked as term approached. The writers believe that this response may be utilized as an index of the maturity of the fetus. Richards and his associates (70, 71) studied fetal activity in relation to the basal metabolic rate of the mother, and other prenatal conditions, as well as in relation to later developmental measures.

Neonate Responses

Studies of infants during the first ten days after birth have been more numerous than investigations at any other age level in infancy. This is probably not due to a belief that the neonatal period is of outstanding importance, but rather to the fact that the newborn in maternity hospitals are accessible to qualified investigators, whereas at any later age (up to the nursery school period) unselected groups of children are difficult to obtain. A number of investigations have dealt with reflexes such as the Moro and the startle reflex (15, 16, 25, 41, 42) ; the plantar reflex (16, 73) ; and the patellar reflex (37). Sherman, Sherman, and Flory (74), in a carefully planned and controlled experiment involving 317 infants under sixteen days of age, made a study of the patellar, plantar, Achilles, Brudzinski, and grasping reflexes together with the infant's responses to a number of stimuli of varying modalities and intensities, including light, pain, and

[1] Bibliography for this chapter begins on page 111.

pressure. Defense movements of the arms and hands were found to increase in adequacy irregularly with age within the short period covered. Crudden (18) studied the responses of nine neonates to thermal stimuli. Delman (20), using tactile stimuli, studied the extension of responses to limbs other than the one stimulated. Dennis (25) gave evidence pointing toward the conclusion that the Moro reflex does not wane and disappear at the age of about three months as has been generally thought, but rather that at this age it begins to be inhibited by other responses. The Moro response cannot be elicited unless the child is relaxed, and the normal child over six months is seldom relaxed under the conditions of a test. Dennis found that the characteristic Moro pattern of arm and leg movement can be produced in older children if the child is tested in a relaxed condition.

Pratt (62, 63, 64), who made extensive investigations of the activity of the neonate, wrote that the early activity of the infant is chiefly generalized activity, that "most of the responses tend to involve most of the major segments of the body and that the participation of smaller parts is likewise quite conspicuous." He concluded, "It may safely be affirmed that from the stimulus-receptor aspect there is no evidence for a high degree of specificity of behavior in the newborn infant." A factor of possible relevance to the development of intelligence and motor control is the amount of activity which the infant engages in, either when lying undisturbed (outwardly at least) or in response to prearranged stimuli. The activity of newborn infants under various conditions has been measured by Richards (68, 69), Smith (78), and Redfield (67).

Studies of conditioning behavior by Wenger (85) and of behavior in inverted position by Irwin (44) for infants under ten days of age are treated in sections which follow.

Tests and Other Technics of Infant Study

Gesell Tests

Gesell and Thompson (33) provided a long looked for revision of the Gesell tests for infants up to one year of age. The revision was based on data collected from 524 examinations made on 107 normal infants from parents of north European descent and of average socio-economic status, education, and interests. The examinations were made at four-week intervals on children between the ages of four and fifty-six weeks. One group of children was used between the ages of four and sixteen weeks, and another between the ages of sixteen and fifty-six weeks. The number of examinations made at each age level varied from 24 to 48 with an average of 37. The number of boys and girls was approximately equal.

Forty behavior situations were described and under each was listed the percent of infants of each age making the response. The situations and procedures were in most cases similar or identical to those given in Gesell's earlier books but were more precisely and rigidly defined. Maturity level

summaries were given for each of several types of behavior—head control, arm-head posture, leg-foot posture, body posture and progression, regard, prehension, social behavior, and adaptation. The directions for administering and scoring were sufficiently detailed and precise for use by any experienced examiner familiar with infant behavior, and a method was provided for reducing the final ratings to a "behavior age" which could be treated statistically.

Nelson and Richards (60, 72), using the original form, reported biserial correlation coefficients between the individual items and the total score, at six months, varying from .88 to .37. They also reported correlation coefficients between Gesell scores at six months, and performance on the Merrill-Palmer test at twenty-four months, and the Stanford-Binet at thirty-six months. A small number of items, combined in certain ways, gave multiple coefficients as high as .70 with the Merrill-Palmer tests at two years and .80 with the Stanford-Binet tests at three years. The test items that correlate highest with a later test involve distance perception and "awareness" or alertness. Between the total Gesell tests at six months and the Merrill-Palmer at twenty-four months ($N = 48$) the coefficient was .37; with the Stanford-Binet at thirty-six months ($N = 31$) .46; and with the Merrill-Palmer at twenty-four months combined with the Stanford-Binet at thirty-six months, .66. These coefficients are somewhat higher than have been generally found.

Richards and Newbery (70) found the surprisingly high correlation coefficient of $.62 \pm .18$ between the amount of fetal activity and scores on the six months' Gesell schedules. When the small group of twelve cases was divided into three groups according to their fetal activity scores, those which averaged highest also averaged highest on the Gesell tests and those which were lowest in the fetal activity scores were also lowest on the Gesell scores. Only twelve cases were studied.

Kasambi (49) suggested methods and procedures for standardizing the Gesell tests for use with Indian children. He recommended the inclusion of several additional items involving the attainment of objects by means of a string and from behind glass.

Vienna Baby Tests

A revision and extension of the Vienna baby tests by Bühler and Hetzer (12) was published in German in 1932 and translated into English in 1935. Hetzer and Braun (39) compared the results of the diagnosis made by means of these tests with that made by a pediatrician on a small group of children. Herring (38) gave 159 pairs of tests to infants under fifteen months of age with an interval of one or two days between the first and second tests. The number of cases in each age group ranged from 27 to 8. The split-half correlation coefficients averaged .86. The reliability coefficient determined by correlating the developmental quotients of the first test and the retest, age range fifteen months, was .83. Between age and

raw score the correlation was .99. Retest coefficients after longer intervals were low (.29 ± .14) between DQ at one month and combined DQ's at five and six months; .45 ± .12 between combined DQ's at five and six months and combined DQ's at nine and ten months. The median DQ was 114, suggesting that the age standards are probably too low. Herring concluded, "Though the tests seemed to indicate a fair degree of reliability over a limited time interval, the predictive value for a long period of time is slight."

Hubbard (40), using an earlier edition of the tests and reformulating the directions where they were vague or incomplete, made 124 tests on babies attending a well-baby clinic. Thirty-eight babies were retested once and eight were retested twice. The corrected split-half method of correlation gave reliability coefficients of between .54 and .95. The average change in DQ between the first and second test (average interval four months) was ten points, and the correlation coefficient .70. Correlation coefficients between the Bühler and Merrill-Palmer tests in groups of 15 and 25 cases were found to be .37 and .70, respectively. Hubbard is more optimistic as to the predictive value of these tests than are most authors.

Iowa Tests for Young Children

Fillmore (27) constructed a test for infants between the ages of 4.5 and 23.5 months. She included 49 test items, most of which were similar to or identical with those used by Gesell. They were scaled according to Thurstone's method. The split-half correlation method gave reliability coefficients varying between .88 and .93. The mean square contingency coefficients between tests repeated at intervals under thirteen months was .26. Correlation coefficients between individual items and later IQ's obtained from the Stanford-Binet and the Kuhlmann-Binet tests varied from .47 to — .32. Correlations of total test score with later IQ ranged from .47 to .03.

Motor Ability Tests

Bayley (4) constructed a scale of 76 items for the measurement of motor control up to three years of age. From 44 to 61 infants were examined each month during the first fifteen months after birth and every three months between the ages of fifteen and thirty-six months. Norms and directions for administering the scale are given. The reliability coefficients by the split-half method for the various age groups varied from .49 to .91 with a mean of .77. The correlation coefficient between tests repeated one month apart averaged .71, but when the interval between tests was increased to six months the coefficients dropped considerably. The author concluded that increments of both mental and physical growth decrease with age and that items pertaining to motor ability show more rapid growth during the first twenty-one months than do items of mental ability, after which age the former develop more slowly than the latter.

Reports by Mothers

Pyles, Stolz, and MacFarlane (66), in a study of the accuracy of reports by mothers, compared the developmental data which had been collected during the child's first year with reports made by the mothers when the children were 21 months old. The average error of report of birth weight was only two ounces, while the error for duration of labor was three and one-half hours. Injury during labor, use of instruments at birth, and amount of illness during the first year were very inaccurately reported. The ages of first walking and of eruption of the first tooth were more accurately reported, but still left much to be desired. Inaccurate as the reports were, they are doubtless more accurate than reports made at the time of school or college entrance, when such data are sometimes collected.

Cinema Records

During the last three years there has been an increase in the use of the cinema as a tool or means of studying infant behavior and of portraying the development of motor control. The usual procedure is either to arrange a natural situation and photograph the infant's spontaneous behavior, or to set up special experimental situations and photograph him as he responds to prearranged stimuli. After the behavior has once been recorded on the films it may be studied at leisure. The films can be run off an indefinite number of times and at whatever speed may be desired. Films are not only being used more and more for purposes of investigation, but they are also becoming more widely circulated for classroom or laboratory use in other institutions.

McGraw and her associates produced several films at the Normal Child Development Clinic of Columbia University. One (54) containing eight reels showed the sequential development of particular behavior patterns in two infants, "Johnie and Jimmie," and the effects of special exercise. McGraw and Weinbach (58), in a 300-foot film, showed a method of studying erect locomotion by picturing the manner of walking and the footprints on the same film. In another film McGraw and Price (55) showed the behavior of infants ranging in age from six to nineteen months when placed in test situations involving obstruction by means of plate glass. Kantrow (47) and Wildenberg and Irwin (86) prepared a film showing the apparatus and the technics used in establishing conditioned responses in young infants. Bayley and Jones (5), in a 400-foot reel, demonstrated the various reflexes and the responses of an infant up to one year of age to the mental and motor ability tests.

Baby Biographies

Hurlock and McHugh (43) collected data from a number of baby biographies and compared them with Mead's group of feeble-minded babies, Terman's gifted group, Shirley's group of unselected children, and with

some of the infant test norms. They concluded that child biographies do not lend themselves to combination so as to make possible a general picture of babyhood. Dennis (22), on the other hand, found baby biographies of considerable value. He compiled and published a bibliography containing 64 titles of biographies of babies under three years, each of which deals with at least two phases of development. In another study Dennis and Dennis (21) tabulated the usable data for the first year of life from forty of the fullest biographies available. Only items that were reported and dated by at least ten authors were used. The list included fifty items. Objective definitions were formulated for each and the means were compared with those of Shirley. Only slight discrepancies were found between the two sets of data.

Factors Affecting Development

With the reliability, validity, and predictive value of infant tests of general mental and motor abilities being as doubtful as is indicated by studies in the foregoing section, and with further doubt as to whether infant mental tests measure the same abilities as tests for the older ages, one cannot study the rate of growth of infants with confidence. Indeed, Richards and Nelson (72), who perhaps made the most careful study involving repeated measurements, and also Hubbard (40) and Fillmore (27), presented their material as studies of test reliabilities rather than of growth. The development of rather narrow abilities, such as language, grasping, and locomotion, can be studied with more confidence. Comparisons of groups of infants of the same age, measured by the same tests, may also be made with some degree of confidence where factors other than the traits being studied can be controlled. The present section will deal with conditions of general growth and the succeeding section will present studies of the narrower abilities.

Race

Curti and others (19) measured a group of colored infants in Jamaica by means of the Gesell tests and compared the results with the New Haven children measured in Dr. Gesell's clinic. The Jamaica children were found to be definitely inferior. But, as the authors pointed out, the two groups of children came from very different cultural and socio-economic backgrounds. There are a number of factors besides race which may have contributed to the inferiority of the Jamaica infants, such as selection of cases, poor diet, barren physical surroundings, and lack of stimulation.

Prematurely Born Infants

Melcher (59) found a group of 44 prematurely born babies to be appreciably below average at three months of age, but by five months they had reached the norm and later the average DQ was above 100. Up to eighteen months when the study was concluded, a definite tendency for

retardation in motor and posture control was noted. Baedorf (3) examined 27 children between the ages of five and seventeen years who had been prematurely born. Twenty-two were of normal intelligence, one injured at birth was an imbecile, and the remaining four were slightly backward or of borderline intelligence.

Quintuplets

Blatz and others (7, 8, 9, 10) reported that the Dionne quintuplet sisters are below average mentally as shown by the Gesell, Merrill-Palmer, and Kuhlmann-Binet tests. The retardation is greatest in language and least in motor functions. Blatz wrote that the children are growing more rapidly than average, and predicted that they will have caught up to the norm by the age of five years.

Nurture

The evidence of the effects of the infant's environment on his mental development are contradictory. Skeels (75, 76, 77) found that children from parents of low intelligence and low socio-economic levels, placed in foster homes before the age of six months, developed mental ability markedly superior to that which would be expected from their hereditary background. In a study of 73 cases, 87 percent of the true fathers were found to be in the lower three levels of a seven-point scale of occupational classification and 46 percent were in the lowest level. On the other hand, only 26 percent of the foster fathers fell in the lower three groups and only one case in the lowest group. Fifteen children whose true mothers had IQ's below 80 had a median IQ of 116. The mean IQ of the 39 mothers who were given tests was 84 and the mean IQ of their children was 117. Only one child was below average, and 34 percent had IQ's of 120 or higher. The correlation coefficient between the IQ's of the true mothers and their children was zero. Under the age of two years no relationship was found between the occupations of the adoptive fathers and the child's IQ. The cause of the high IQ's of the children is not evident. The author suggested the possibility that the parent-child relationship may be a factor. Foster parents are usually vitally interested in having children and may provide a more stimulating environment through play equipment, answering questions, etc., than is provided for the average child.

Snygg (80) found a very low order of relationship between the IQ's of 312 children living in foster homes and the IQ's of their true mothers. The correlation did not increase with age. Crissey (17) took children from the probably unstimulating environment of an orphanage for his subjects. He did not treat the children under two years of age separately. Under four years of age, a loss in IQ occurred during residence in the orphanage for periods of from twelve to eighteen months. The mean loss of children originally tested at one year of age was ten points.

Bayley and Jones (6) found slight negative or zero correlations between the socio-economic status, education, occupation, etc., of the parents and mental test scores of 61 children up to eighteen months of age. After eighteen months the correlations are positive and tend to increase with age up to five or six years. Correlation coefficients between motor ability scores and various environmental factors also approach zero. Herring (38), in agreement with the foregoing, found no difference in the mental test scores of infants under fifteen months, when classified in groups according to socio-economic status. Dennis (23) supervised the bringing up of two babies during their first year. These babies were given good physical care but a minimum of handling, of reward, and of punishment. Each infant was left as much as possible to his own devices in behavioral development. All the typical responses of the first year developed within the usual age period for normal children. The responses included laughter, timidity, play, and vocal greeting. The author believed that these activities did not occur instinctively, but developed through the child's own activity with only a minimum of stimulation from adults.

Development of Particular Responses

Conditioning

Wenger (85) succeeded in forming conditioned responses in children as young as four to eight days. Beginning with the second postnatal day, three infants were subjected to a light stimulus and at the same time to a vibration applied to one foot. Training was continued for two to three hours a day, at intervals of forty-five seconds to three minutes. All three infants showed evidence of conditioning (eye-lid closure when the vibration was applied to the foot) after from two to five days of training. The conditioned response, however, had not become stable when the infants left the hospital at the age of ten days. Wenger (85) also established a definite conditioned withdrawal response to tone in three of five infants. The other two cases gave less definite indications. He was unsuccessful in establishing conditioned feeding responses to the sound of a buzzer. In one of his two cases the training was begun on the sixteenth day and was continued for eighteen days, and in the other the training extended from the first feeding after birth through the eighth week. Wenger concluded that conditioning in the neonate was unstable and not easily obtained.

Kantrow (46, 47, 48) conditioned feeding responses to the sound of a buzzer in sixteen infants ranging in age from six to fourteen weeks. Stable conditioned responses were established after from three to nine experimental feedings or in from one to five days, which involved a total of from sixteen to fifty-three paired stimulations. The conditioning was retained up to 72 hours. The age at which the conditioned feeding responses were established varied from 46 to 118 days. No relationship was found between the time required to establish the conditioned response and the

age of the child or scores made on the Kuhlmann-Binet intelligence test. Four to twelve single stimulations extinguished the response. Gesell (29) warned that artificial conditioning may be harmful. He said: ". . . stimuli which are apparently innocuous may be noxious to him (the infant). It would be ironical if the experimental analysis of the conditioned responses of the young infant resulted in the production of abnormal behavior rather than in an understanding of the therapeutic value of the methods of the C-R." Gesell, however, offered no proof of grounds for his fears.

Locomotor and Posture Control

Abramson (1) wrote a detailed description of the development of motor and postural control of infants based on a review of the literature on development of motor control, maturation of the nervous system, myelinization, and other pertinent physiologic and metabolic processes. He said: "The advancement of growth is logical and regular in its serial order, being governed apparently by biologic laws strikingly similar to those controlling the logical course of physical growth. Just as in physical development growth spreads downward from the cephalic end of the organism in a caudal direction, similarly in the development of basic motor skills control migrates down through the body from head to tail with a concurrent spread of coordination out to the extremities."

Ames (2) collected detailed data on the development of locomotor ability of five infants, making extended use of cinema films. The data from the five children were supplemented by a less extensive study of fifteen additional cases. Ames described fourteen definite stages through which the child passed as he progressed toward erect locomotion. The increasing importance of the foot in the development of creeping is considered by the author as the most important fact brought out by the study. Thompson (82) presented an equally detailed analysis of the stages through which the infant attains the erect posture. She pointed out that "the infant can maintain an orthograde stance before he can attain that posture and, therefore, certain behavior traits appear to emerge with suddenness which in reality have had slow and gradual growth."

McGraw (57) and McGraw and Weinbach (56, 58) analyzed cinema records of infants' footprints with reference to base width, pressure contacts, associated movements, shifts from isolated to integrated movements, and equal spacing and timing of steps, and concluded that such factors are more important indexes of progress than are the number of steps taken by the child. The steps of the infant just learning to walk are unequal in time. He places one foot before he starts to move the other, while the older child will start to raise the second foot before he has completely placed the first. The child of six months when making stepping movements will usually contact the floor with the toes and ball of the foot only; when walking first begins the whole sole is placed in contact with the floor; as skill is developed the contact becomes heel-toe. McGraw and Weinbach

(56) found that the infant's skill in some activities could be greatly increased by practice while she was able to influence other activities little if at all. She took exception to the common belief that there is danger of overstimulating the infant. She wrote: "There is no problem as to *how much* stimulation an infant may sustain. It is, in my opinion, entirely a matter of the *manner* in which he is stimulated or activated to engage in certain performances."

Levy and Tulchin (51) presented data, collected from baby shows, on age of standing with and without support and of walking with and without support. They explained walking on all fours as either the result of a spastic condition of the legs or a natural transition between creeping and walking. Kume (50) recorded the posture and locomotor development of his own child and compared its development with the norms given by Gesell, Bühler, Shirley, and others. Frank (28) investigated the effects of assisting the infant to roll over and sit up when he was learning these activities spontaneously. The activity of the child when assisted by the adult's hand was found to differ markedly from that which takes place when the child performs the act without aid. When he is assisted there is lack of integration of the parts moved, and neither in the process of an activity nor in any maintained position did he acquire a posture curve similar to that which he attained when unassisted.

Inverted Posture

The posture of infants when grasped above the knees and suspended in an inverted position was studied by Irwin (44) with the aid of cinema films. During the first ten days after birth most of the infants momentarily raised their heads backward; the characteristic position of the arms was flexion upon the chest or at the side of the head. By the third month the reaction became more pronounced and occasionally also involved the lumbar region. During the second three months the lumbar region was usually involved in the response and the flexion of the arms was less. At this age the posture was often held for several minutes. During the second half year these reactions disappeared, and there was a bending forward at the head and waist. In the second year the characteristic response was the retraction of the head with a quick movement and downward extension of the arms with fingers reaching toward the floor. At about two years of age if the child was lowered he would usually walk forward on his hands.

Grasping

Reflex and voluntary grasping of infants, both as recorded in the literature and from the findings of original studies, was reported in great detail from Dr. Gesell's clinic at Yale University. In most cases the data were collected by means of cinema records. Halverson (35), from an analysis of cinema records, concluded that the reflex grasping of the young infant

is a complex process with two phases. The fingers first close against the rod and then clamp on it. He wrote that the manner in which an infant closes upon the rod differs sufficiently from his manner of squeezing it so that the change from one phase to the other is quite distinct. In general, the older the child the more completely the one response is blended with the other. The closure of the hand, it was reported, is the response to the stimulation of the palm. Tightening is the response to the strain against the tendons of the fingers. The time required for closure was found to vary but little with age, while the time of tightening varied inversely with age; the time required at sixteen to twenty weeks was only half of that required at four weeks. Other phases of reflex grasping treated are date of appearance, date of disappearance, length and tenacity of clinging, age of maximum strength, reflex grasping of different materials, and response to light pressure on the palm. In other articles Halverson (34, 36) reported studies of a number of factors related to grasping, among which may be named clinging strength of individual fingers, various aspects of hand pressure strength, etc. In collaboration with Gesell (30), Halverson described in almost equal detail the development of voluntary grasping of the older infant from simple adduction of the thumb through partial opposition to final complete overhead opposition. In the progress from adduction to opposition the authors found "a shift of functional predominance in which the radial digits replace the ulnar digits in grasping."

Handedness

Dennis (24) took care to prevent favoring one hand more than the other in the case of two infants from the forty-eighth to four hundred and twenty-eighth day. Both developed a preference for the right hand. The preference of one of them was much more marked than that of the other.

Feeding Responses

Gesell and Ilg (32) used cinema records for an elaborate and detailed study of the feeding behavior of infants. Ten children were followed to one year of age, nine to two years, and five to three years. The book in which the study is reported is profusely illustrated with detailed descriptions of the mechanisms, processes, and development of sucking, swallowing, mastication, and hand-to-mouth reactions. A chapter is devoted to the child's use of the cup and another chapter to the development of ability to handle the spoon.

Form Perception

Brunswick and Cruickshank (11) presented to infants between the ages of three and eight months objects of different sizes at such distances as would give equal retinal size, and objects of the same size at different dis-

tances. The purpose was "to determine whether there could be found a phase in early perceptional development in which bodies at different distances but of the same retinal projective size are confused, or whether constant, that is, adequate responses to the physical properties of the bodies in the environment are established in spite of the random changes in their retinal size representation." At four to five months there was found but a relatively slight degree of size constancy. At about six months of age a different response was shown to the near and the far objects.

Color Response

Chase (14) demonstrated that infants between the ages of fifteen and seventy days can distinguish between colors of the same light intensity. He devised a method of presenting to the child a moving spot of color on a background of a different hue but of the same intensity. Four colors were used in twelve different combinations. All 24 subjects distinguished some of the color combinations and according to the author "all the cases where no response to color combinations are indicated . . . can be accounted for by the fact that the infant's attention was not centered upon the moving stimulus."

Smith (78, 79) and Peiper (61) found marked differences in the activity of infants under lights of different hues. The aim of Smith's study was "the determination of the relative brightness value for the newborn infant of the hues blue, green and red with the same physical energy." Blue inhibited activity to the greatest extent, and red the least. Girls appeared to distinguish colors, especially red, better than boys. The author concluded that "when the brightness values of the three hues for the newborn infants are compared with those of the same hues for the normal adult and for the various color-blind classes, it is seen that the values for the boys correspond closely to those for the totally color-blind adults, the monochromats. The values for the girls are similar to those for the protanopic class, the partially color-blind who do not see red."

Language

Low (53) recommended a method of studying language development in children which combines a number of the older methods. As a demonstration of his method the author presented a study based on two children between the ages of one and eight years. He pointed out that the child who is superior in one phase of his language development may not be so in another phase, and criticized the use of the length of sentence or of any other single criterion as an all-round measure of language development.

A study by Blatz and others (7, 8) showed the speech of the Dionne quintuplets to be markedly retarded in comparison with a control group at the Saint George's Nursery School and in comparison with norms for twins. They are, however, showing gains in relation to the norm.

Lewis (52) tabulated the data on language development published in a number of baby bibliographies under the following headings: (a) sounds uttered spontaneously by the child during the first year, (b) sounds uttered in immediate imitation during the first year, (c) children's earliest words, (d) use of consonants in words, and (e) response to utterances of others. Using this material, together with data that he had collected, and the writings of other authors, he has prepared an account of the early stages of the development of language in children.

Persistence of Traits

Gesell (31) analyzed cinema records of five infants at one year of age in respect to fifteen behavior traits, observed the same children at the age of five years, and concluded: "Granting inevitable limitations in the application of the method, these results indicate a high degree of latent predictability in behavior traits manifested in the first year of life. Furthermore, the results do not suggest that fundamental individual differences increase markedly with age." In three children energy output, motor demeanor, self-dependence, emotional expressiveness, readiness to smile, and social responsiveness, and for two of the same three cases, communicativeness and adaptivity, received ratings at six weeks of age similar to those which were assigned to them at five years.

tances. The purpose was "to determine whether there could be found a phase in early perceptional development in which bodies at different distances but of the same retinal projective size are confused, or whether constant, that is, adequate responses to the physical properties of the bodies in the environment are established in spite of the random changes in their retinal size representation." At four to five months there was found but a relatively slight degree of size constancy. At about six months of age a different response was shown to the near and the far objects.

Color Response

Chase (14) demonstrated that infants between the ages of fifteen and seventy days can distinguish between colors of the same light intensity. He devised a method of presenting to the child a moving spot of color on a background of a different hue but of the same intensity. Four colors were used in twelve different combinations. All 24 subjects distinguished some of the color combinations and according to the author "all the cases where no response to color combinations are indicated . . . can be accounted for by the fact that the infant's attention was not centered upon the moving stimulus."

Smith (78, 79) and Peiper (61) found marked differences in the activity of infants under lights of different hues. The aim of Smith's study was "the determination of the relative brightness value for the newborn infant of the hues blue, green and red with the same physical energy." Blue inhibited activity to the greatest extent, and red the least. Girls appeared to distinguish colors, especially red, better than boys. The author concluded that "when the brightness values of the three hues for the newborn infants are compared with those of the same hues for the normal adult and for the various color-blind classes, it is seen that the values for the boys correspond closely to those for the totally color-blind adults, the monochromats. The values for the girls are similar to those for the protanopic class, the partially color-blind who do not see red."

Language

Low (53) recommended a method of studying language development in children which combines a number of the older methods. As a demonstration of his method the author presented a study based on two children between the ages of one and eight years. He pointed out that the child who is superior in one phase of his language development may not be so in another phase, and criticized the use of the length of sentence or of any other single criterion as an all-round measure of language development.

A study by Blatz and others (7, 8) showed the speech of the Dionne quintuplets to be markedly retarded in comparison with a control group at the Saint George's Nursery School and in comparison with norms for twins. They are, however, showing gains in relation to the norm.

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CHAPTER II

Mental and Motor Development from Two to Twelve Years[1]

NANCY BAYLEY

The Development of Intelligence

DURING THE PAST three years studies have placed considerable emphasis on curves of growth and especially on the growth of individual children. Richardson and Stokes (269), applying Thurstone's absolute scaling technic to test scores for children of from six to fourteen years of age, found a "g" curve which they extrapolated from birth to twenty-four years. This curve showed positive acceleration at first, with an inflection point around four years of age, and with negative acceleration becoming more marked at about thirteen; continued growth occurred to twenty-four. R. B. Cattell (116) has constructed a curve on his tests for the age range eight to fifteen years. McManama (219), using Spearman's method, found that means of test scores from nine to nineteen years increase regularly with age. Pintner and Stanton (258), testing 140 children repeatedly at yearly intervals in Grades I to VIII with the CAVD tests which have been scaled for absolute units of increment, found the curve of growth to be negatively accelerated and parabolic in form. Freeman and Flory (137) presented a curve of the mean scores for 469 children who were tested repeatedly at yearly intervals from eight to seventeen years. This curve shows "a slight acceleration in preadolescence." Bayley and Jones (6) gave curves of the mean absolute scale values for two sets of thirteen children who were tested repeatedly from birth to four and a half years. These curves show rapid early growth, with an inflection point and slightly negative acceleration appearing around four years. Although there is variation in the forms of the various curves reported, some are very similar and all of them show approximately equal yearly increments of growth between the ages of six and twelve years.

There are several studies on the nature or "organization" of intelligence—of the functions which are being measured by "intelligence" tests as they are manifested in the process of growth. Anderson (92) maintained that during growth behavior changes from generalized responses to more specific ones; he discussed the functional relation of the organism to its environment, and pointed out the limitations imposed on behavior by structure and by developmental level. Werner (306) held that learning is not a unitary function but is achieved by increasingly complex

[1] Bibliography for this chapter begins on page 114.

process-patterns, which change as the child grows older. Piaget (255) divided intellectual evolution into three levels—sensori-motor, egocentric thought, and rational coordination. Thompson (292) called attention to three aspects of growth which should be recognized—augmentation, differentiation, and conjugation or integration. Bühler and Hetzer (13) distinguished six fields in which development takes place throughout the first six years: sense reception, bodily control, social reactions, learning, manipulation, and mental production.

Statistical analyses of the data in this field point out more explicitly the complex nature of children's intelligence. For children of ages eight to fifteen years, Monnin (234) found with increasing age a decreasing independence in the functions measured. She used the method of tetrad differences, and in one study (234) differentiated verbal and numerical abilities; in another (233) she compared tests designed to measure comprehension, invention, criticism, and attention to a sensori-motor task. Conversely, however, Garrett's summary (140) and further analysis of a number of studies made at Columbia University indicated that such functions as verbal, number, and spatial abilities and memory are much more closely related to each other in children than in adults. The studies on which he based his comparisons included one on memory in five-year-old children, and one on verbal, number, and spatial abilities in third- and fourth-grade children, as well as similar studies of adults. His results were in substantial agreement for both the method of tetrad differences and Thurstone's centroid method of factor analysis. Schiller (275) gave a series of twelve tests to 400 nine-year-olds, and by Thurstone's method found four factors to account for 65 percent of the variance. Wenger and Freeman (305) made a factor analysis of a nonverbal test given to children ten and one-half to thirteen and one-half years of age and factored out memory ability and a "power" factor.

Individual Rates of Growth: Constancy of the IQ

In accord with the findings on the complex nature of "intelligence," many recent studies have disclosed evidence of an inconstant IQ and of wide variations from the mean curve in the rates of growth of individuals. In these studies we still find examples in which the author has grouped together individuals of varying ages and with varying intervals between tests. There is an increasing tendency, however, for investigators to attempt the control of age and interval differences, and to report longitudinal studies in which the same children have been tested repeatedly at regular intervals over a fairly long time.

Outstanding among the longitudinal studies are those of Freeman (138, 139) and Freeman and Flory (137). In these studies 469 children were tested at yearly intervals between the ages of eight and sixteen years on a carefully selected battery of tests which exhibited practically uniform increments in difficulty of the scores over the age-range studied. They found

large and consistent individual differences in the rates of growth of ability among the children tested over a period of six to ten years. Individual curves illustrate these differences as definite trends, and correlations between tests given five to ten years apart are so low that it is obvious that adequate prediction of later ability cannot be made from tests given at early ages. The individual curves usually show consistent growth rates for short periods of two or three years, but a child is very likely to deviate from such a trend and develop more rapidly or more slowly at a later period. In the preadolescent period the brighter children tend to develop more rapidly than the average, and the duller tend to develop more slowly, but this does not hold true at later ages.

Honzik (171) made a study of 252 children who were tested repeatedly at yearly or six-month intervals from twenty-one months to seven years of age. She found test performance to be relatively constant over short intervals of time, but decreasing in constancy with increasing time between tests, particularly at younger ages. Retest correlations varied in magnitude according to the ratio between CA at the first test and CA at the second test. The correlation between this ratio and the retest coefficients at the various age and time intervals was .92 for one form of the California Preschool Scale and .78 for the other. There were marked individual differences in test constancy; some children maintained their relative position in the group throughout the five-year period, while others shifted radically in their scores.

Wellman (302) presented further data on studies of Iowa children who had been tested repeatedly from preschool to college. Correlations, individual curves, and other comparisons showed wide individual differences in rates of mental growth. Bayley and Jones (6) presented individual curves of several children tested repeatedly from birth to four and one-half years. These curves of absolute scale scores are not steady but show inconstant rates of growth. E. A. Lincoln (202) found for children in the Harvard Growth Study that there was a tendency for greater changes in IQ when the intervals between two tests were longer. Changes were also greater for children with high initial IQ's. Rosenfeld and Nemzek (271) compared IQ's on the Detroit First Grade Test with twelfth-grade IQ's of 200 pupils and found a correlation of .31 between the two sets of scores. Pintner and Stanton (258) found wide fluctuations in individual gains made by 140 elementary-school children who were tested annually for periods of from two to six years.

Asch (95) has shown, by testing a group of children at nine years of age and again at twelve, that the organization of mental abilities has not remained constant over this period, but that the various factors tested change in their interrelationships.

Mowrer (238) reported an average change of 13 IQ points in nursery school children tested on the Minnesota Preschool Scale and the Stanford-Binet, where the Stanford-Binet retests were given after an average inter-

val of twelve months. Seagoe (278) obtained *r*'s of .50 and .65 between first-grade and fifth- and seventh-grade test scores. She concluded that the earlier performance tests measure different functions from those of the verbal tests given in the later grades, and that therefore the early tests are not valid measures of later school performance. Town (294), avoiding numerical comparisons, felt that the IQ is not adequate for prediction of mental ability.

In spite of this overwhelming evidence that mental growth is not steady and constant throughout the span of growth, a few studies report in favor of constancy. Lorge and Hollingworth (207) found that the very superior children studied by them remained so, and that superior status on the Stanford-Binet at seven to nine years in predictive of status on the Army Alpha at sixteen to nineteen years and on the CAVD tests at or near maturity. Perhaps if one selects sufficiently high IQ's, even fairly large fluctuations downward leave a child still in the upper 5 percent of the population. Arthur (94) gave the Kuhlmann-Binet to 155 children from kindergarten through the second grade and retested them with the Kuhlmann-Anderson in Grades V to VII. She obtained a median change of five IQ points, the most usual change found for retests of school-age children, and concluded that the predictive value of the test scores is satisfactory. When she divided the children into IQ groupings of ten-point intervals 47 percent remained in the same group on the later test, 47 percent changed one step, and 7 percent changed two steps. Gesell (143) gave examples illustrating the essential stability of mental growth.

Hoakley (170) and Bradway and Hoffeditz (110) presented data showing the greater constancy of the "personal constant" over the IQ. Manwiller (225) found the group averages of tests given in the elementary schools in Pittsburgh over a seven-year period to remain practically unchanged for the total school system.

To those who are concerned with prediction and prognosis of individual children the fact that there are so many cases whose growth is not constant looms important. If, in our attempts to predict later mental growth, we are able to discover the factors which are related to constant or variable rates of growth we may then, perhaps, decide which cases are predictable and which are not.

Factors Related to or Affecting Intelligence

Cultural Environment

Considerable recent research has been conducted on the relation between cultural or socio-economic environment and intelligence. Coffey and Wellman (118) classified 400 nursery school children according to their fathers' occupations and parents' education. These children's cultural status was related to their intelligence test scores, but it was not a significant factor in the changes occurring in the children's IQ's during

their preschool attendance. Bayley and Jones (6) studied the relation of socio-economic factors to the intelligence scores of 61 children who were tested repeatedly from birth to six years of age. Correlations did not become significantly positive until two years of age but after this age some significant *r*'s were found. The highest *r*'s were with parents' education; these were approximately .5 at all ages from two through six years. The next highest *r*'s were with fathers' occupation; low positive *r*'s obtained with family income, a "social rating" of the home and neighborhood, and a socio-economic scale composed of all of the factors considered. The *r*'s with these three latter variables tended to increase with the age of the children. (Results for this study with reference to the younger ages are discussed in Chapter I.)

Pieter (257) obtained the unusually high *r* of .80 between ratings of social status and IQ for 1,500 Polish children. The correlation was less for children with extremely high or low IQ's, suggesting to him that in extreme cases genetic factors are more effective than environmental factors. Lichtenstein and Brown (201) found an average IQ of 92 for 500 children of Grades IV to VIII in a delinquency area in Chicago. Zadrizil (318) computed mean IQ's for children from different occupational groups, and found a difference corresponding to the cultural ranking; the mean IQ of children of day laborers was 91, of children of university trained persons it was 117.

Skeels and Fillmore (280) compared siblings from homes of low socio-economic status who were tested at the time they entered an orphanage. The older siblings, who had spent a longer time in their poor home environment, had lower IQ's than their younger siblings. The authors showed that in normal children there is a similar trend toward lower IQ's with advancing age, but they do not make the indicated correction for their data on the orphanage group. Spielerein (283) compared scores on a translated Binet test given to Russian and European children in the same town with scores on a revised test in which the items were equally familiar to all of the children. The Russians did poorly on the first test but were as good as the Europeans on the second test. This, he felt, is due to the importance of cultural differences in affecting test scores. Cuff (122) found that vocabulary was significantly related to cultural status. Lazar (196) found that environmental opportunities to read corresponded with intelligence groupings of children.

Stout (284), on the other hand, selected a group of ten-year-olds with normal intelligence and found them to vary widely in socio-economic status, mechanical ability, musical ability, school achievement, and behavior tendencies. Lowen (209) found no differences in writing creative poetry between children from schools in good and poor communities, when taught by the same teacher, and when the same methods were used. Better poetry was written by children with IQ's from 112 to 126. Peatman and Greenspan (251) found no differences in superstitious beliefs among

Negro children from rural and urban environments. Other studies have been made by Pieter (256) and Reichenberg (265).

Schooling and Intelligence

The effect of the school curriculum on intelligence has been the object of several studies. Wellman (301,302) matched preschool children for IQ and then compared the subsequent IQ's of those children who attended the University of Iowa training schools for a shorter time or not at all. She found that marked increases in IQ coincided with attendance at the university school, while gains for children attending other schools were small or negligible. These differences are remarkable in comparison with earlier studies and theories on this subject and call for further study and explanation. Lamson (195), on the contrary, found no gains in IQ for children attending the fourth grade of a demonstration school with a greatly enriched curriculum. Peterson (252) compared twenty children who had attended the University of Iowa preschool (nursery school) with fifteen who had not attended nursery school, both groups enrolled in the university's junior primary class. The two groups had similar IQ's and socio-economic backgrounds. Tests of reading readiness, vocabulary, and information yielded no differences between the two groups, but the nursery school children were more aggressive, independent, and sociable and more mature in social competence. Malloy (224) found that after a year in the nursery school, 21 children were more advanced in social behavior and had longer attention spans for both materials and children. Blanton (107) compared Texas children in rural one-teacher schools with urban children and found the rural children to be not only inferior in intelligence and school achievement, but also in socio-economic and physical status.

Foster Homes and Institutions

A number of investigations concerned with the nature-nurture problem have made studies of children in foster homes and of children in institutions. Schott (276) found that gains in IQ made by children after placement in foster homes were not significant when compared with gains on retests made by children from normal populations. Leahy (197) matched 194 adopted children with control "own" children for sex, age, and fathers' occupations and education. The adopted children were placed in the foster homes before the age of six months. The distributions of ages, school grades, and IQ's of the two groups were practically identical. The *r*'s between IQ and cultural status average .18 for the adopted and .51 for own children. Skeels (77) found that correlations between foster children's IQ's and the cultural status of the foster home were near zero, but that the children's IQ's averaged much higher than would be expected from their cultural status. (See also Chapter I of this *Review*.) Snygg

(80) correlated the IQ's of 312 foster children aged one to five years with the IQ's of their true mothers and obtained an *r* of .13. In part of this age range, however, it is usual for correlations between the abilities of even true parents and their children to be zero, while in another part of the age range the correlations are usually positive.

Skodak (281) studied the scores of sixteen children whose own mothers were feeble-minded. The children had been placed in foster homes before the age of six months. Their mean IQ on the first test was 116, on the second 108. These IQ's were very similar to the means of a large group of 154 foster children from which the sixteen cases were selected. When divided into two groups on the basis of foster fathers' occupations the average scores of the two groups differed significantly at both tests. The discrepancy between the findings of this study and that of Leahy (197) is difficult to explain; it may be due in part to difference in methods of treatment of the data. There is no statement made in Skodak's study of the mothers' types of feeble-mindedness, or the conditions under which they were tested. If the mothers' low mentality were primarily hereditary one would expect a certain amount of regression toward the mean in the offspring but not an average above 100. It is notable that the children's IQ's drop, as they grow older, and as they reach the ages at which other investigators have found positive relationships between childrens' scores and their parents' socio-economic status. Even with these considerations, however, there remains evidence for a definite relation between children's test scores and the cultural status of the foster homes in which they are living.

Studying children living in institutions, Crissey (17,121) found that borderline cases increased in IQ if moved from a home for the feeble-minded to an orphanage, while children of similar mentality, if moved from the orphanage to the home for the feeble-minded lost in IQ. The assumption was made that the more stimulating environment of the more intelligent children in the orphanage seemed to keep the IQ's at a higher level, while the lack of stimulation in the other environment allowed them to drop. (See Chapter III for a discussion of Crissey's findings as related to older children.) Hinton (169) studied IQ's of children who had lived in the superior environment of Moosehart for five years, and found no reliable difference resulting from this environment. Nine months of pre-school attendance was found by Skeels (279) to make a group of orphanage children superior in social maturity, but not in intellectual ability, to their fellows who did not attend the school. Smith and Hixon (282) found insignificant differences in intelligence and achievement between orphanage and non-orphanage children. Little and Williams (205) also studied orphans.

Identical Sibs

In the field of twin resemblances, Newman, Freeman, and Holzinger (244) have assembled their studies, especially on identical twins reared apart, and found that environment made most difference in temperament and personality, less in ability and achievement scores, and least in physical traits. Luria and Mirenova (211, 212) trained identical twins, five and one-half to six years of age, by different methods and obtained differences in achievement. After a period of eighteen months the differences began to break down. Luria (210), in another place, stated that the ratio of heredity to environment does not remain constant, but as mental functions proceed (with growth) from simple to complex the nongenetic factors become more influential.

The studies of the Dionne quintuplets by Blatz and his associates (9, 10) have not been carried sufficiently far at present to yield much of significance for this age period. In spite of "identical" heredity, definite individual differences are present and appear to be due in large part to differences in the children's environments and physical status. On the other hand, the differences are small, and there is great similarity in their growth curves in many respects. A study of siblings by King (188) showed that their scores are more similar when they are compared for the same ages rather than at the same time of testing.

Practice and Instruction on Tests

The effect of practice on mental test scores is still being studied, with some new light on specific factors. Adkins (90) reported the increased scores on repeated tests made by children at Moosehart. The SD's increased with practice, and an analysis of the changes indicated that the children who made the highest scores on their first test profited most by the test experience. Anastasi (91), after giving five tests to 200 sixth-grade children, gave them instruction on methods of performance related to three of the tests, and then retested with parallel forms of the five tests. Factor analyses showed that the factor loadings were very different for the two sets of tests. She concluded that factor patterns may be determined by experience, and that they may differ in the same subjects at different times as well as in different populations. Hawk (165) gave training in speech, emphasizing its motor processes; marked increases in IQ resulted. Rodger (270), using a battery of six tests administered from two weeks to three and a half months apart, found that in general the IQ's increased and the more intelligent children were more variable in their IQ's.

Bilingual Pupils

Studies of intelligence scores of bilinguals are not in entire agreement, but the predominant evidence points to a degree of handicap of bilinguals

on verbal tests. Among children of Italian immigrants, Hill (168) compared Stanford-Binet scores, given in Grade I, with Otis and National Intelligence Test scores, given in Grades V and VI, and concluded that bilingualism did not appear to diminish the IQ, and that the correlations were high enough for practical purposes in the prediction of scores between the two grade levels. Mitchell (232), on the contrary, got a mean difference of 13 IQ points on tests of Spanish-speaking children, using two forms of a nonverbal test and giving the directions for one test in Spanish and for the other in English. The author concluded that bilingual children work under a serious handicap on American test scales. A carefully controlled study was made by Barke and Williams (99) on Welsh-English bilinguals in which tests were given in both languages, and English-speaking monoglots in the same schools were given tests in English. Both groups were also given a nonverbal performance test. On the nonverbal tests the two groups were similar, on the verbal tests the bilinguals were distinctly inferior to the monoglots, and more inferior in the Welsh than in the English tests. Monoglots had larger vocabularies.

Miscellaneous Studies

P. Cattell (114) found large differences among IQ's earned by the same children when tested by different persons; some testers consistently gave higher IQ's, others lower. O'Neill (249) selected cases whose retest IQ's varied more than five points and assigned a reason for each shift but did not examine the incidence of these causal factors in the cases showing a smaller change. Davis (127) found "only" girls to be superior in intelligence. Wolf (317) found that girls who were successful academically differed from girls who were failures, in tests of personality and in certain items of the Binet tests. Greig (157) discussed the effects of emotional conflict.

Effect of incentives on scores—Brill (111) found that well-adjusted children made better scores on the Goodenough drawing tests when incentives were offered. Ferguson (134) and Benton (103) both found that prizes and other strong incentives did not increase scores but seemed to have a negative effect. C. Meier's study (227) on word learning gave varying results.

Differential birth-rates—R. B. Cattell (115) and Popenoe (261) reported evidence of declining average intelligence because of the differential birth-rates of high and low socio-economic groups.

Nature and Nurture: Comments

It is apparent, from the various studies here reviewed, that inheritance is not the sole determiner of a child's intellectual status, and that many factors in his environment serve either to stimulate or to retard his mental development. It is extremely difficult, however, to control or to take ac-

count of all of the determiners of mental test performance so as to study the influence of any one of them; and most experimenters resort in part, at least, to hunches or preferences when interpreting their material. Wellman (304), for example, showed a strong preference for cultural environmental determiners of the IQ. She concluded that the IQ is highly susceptible to modification and that IQ trends can be predicted if one has knowledge of the cultural status of a child's home and the curriculum and practices of his school. Such information obviously increases prediction—to the extent that these factors operate. But the effects of "environment" are exerted in complex ways. Homes of the same general cultural status may differ widely in their actual stimulus to intellectual development; emotional and other personality differences in children will alter their response to their environments; chance experiences may change attitudes and interests; and all of these factors interact with one another in various ways. We shall need much more specific information in regard to which factors in the environment are most influential in mental development, and their relation to innate abilities, before we can accurately predict changes in the IQ.

Sex Differences in Intelligence

Small sex differences have been shown for certain tests by several investigators. Lichtenstein and Brown (201) have found girls to excel on several tests. Menzel (229) found East Indian boys to excel on the Goodenough scale. Louttit and Stackman (208) reported higher *r*'s for girls between the Porteus maze and the Stanford-Binet tests. Lincoln's studies (202) of Stanford-Binet retests on the Harvard Growth Study children showed greater gains for boys and greater losses for girls in IQ.

Racial Differences

Studies of racial differences have been, for the most part, carefully controlled and of a nonverbal nature. Chinese children tend to be superior to American standards on the Goodenough test (172) and on the Porteus test (266) and superior to Japanese on the Leiter International Performance Scale (200). American Indians are inferior to whites in most tests, although less on the Pintner nonverbal than on a verbal test, according to Garth and Smith (141), and less inferior if reared in a white foster home (142). In the Seashore tests of musical talent Indians are below the white norms. They are least inferior in rhythm and time, and most in pitch, tonal memory, intensity, and consonance. Japanese, on the other hand, are close to the white norms (272). Negroes continue to test inferior to whites in intelligence, although cultural and other environmental factors could not be completely ruled out (201). Long (206) studied the relation between the IQ's of Negroes and their school achievement; within single grades, he reported a tendency for these to vary inversely.

Arsenian (93) found Jewish children superior to Italians on the Spearman Visual Perception Test. Harmon (162) found speed of reaction to be fastest and most stable for Italians. Great individual differences were present in all races. American whites are intermediate in these racial comparisons.

Superior Children

E. A. Lincoln (203) compared retests of children whose IQ's on the initial test ranged from 119 to 145. The retests were made after intervals of from one to five years. The IQ's of these children dropped substantially, especially those of the girls. H. Lincoln (204) found little correlation between scores on the Cornell-Coxe and the Stanford-Binet tests of superior children, the deviations from the Stanford-Binet ranging from —26 to + 46. In general there was a tendency for the Cornell-Coxe scores to increase. MacMurray (220) gave the Pintner-Paterson tests to fifty children with IQ's ranging from 120 to 189 on the Stanford-Binet. There was a mean drop of 10.8 IQ points; while for fifty dull children (IQ's from 63 to 107) there was a mean increase of 9.4 IQ points on the Pintner-Paterson scale. The low ceiling on some of the Pintner-Paterson tests invalidates the scale for the high deviates.

Gifted children have been tested and observed for characteristics of personality in which they might deviate from average children. Nevill (242) selected 78 clinic cases with IQ's from 140 to 180, and found that of the thirty-five problem cases many of the problems were like those of children with normal intelligence, including scholastic backwardness. Street (285) selected 93 superior children in Grades IV, V, and VI. They were three years advanced in both MA and social age, took part in extra-curriculum activities, and in general were much better adjusted to the environment than the average. Zorbaugh (320) studied five cases with IQ's above 180 and found no evidence for the association of giftedness with instability. In general, these researches corroborate earlier findings that mentally superior children usually also have the advantage in other traits of personality. Witty (316) found, however, that very few among fifty children with IQ's over 140 developed drives which were adequate for them to achieve conspicuous creative production. He concluded that the schools' standards are inadequate for such children.

The subject of gifted children is treated by Bentley (102). Noonan and Norris (245) have reviewed the literature on research in this field. Goldberg (148) presented a clinical study of a superior child.

Retarded Children

Kinder and Humphreys (187) reported the value of the observation-room method in studying mental defectives. Kinder and Hamlin (186) found that subnormal subjects usually tested higher on the Pintner-

Paterson scale than on the Stanford-Binet. Gordon (153) analyzed defectives' scores on the Merrill-Palmer scale into the types of performance in which they did best, poorest, and so on. Wile and Davis (308) found that mental defectives have basal ages closer to their MA's than do normal and superior children. The defective children's basal ages were also closer to their reading ages than to their age-grade status. C. Meier (227) increased word-learning in subnormal children by offering prizes, but the prizes lost their effectiveness when they became familiar to the children.

Ramer (264) found a large number of background factors operative in 464 mentally defective children, and showed the need to consider other than measures of intelligence. Glueck (147) compared the mental retardation of juvenile delinquents with that of delinquency areas from which these children come and found them to be similar. He concluded that these children were delinquent not because of their low mentality, but because they came from inferior environments and from families which were incapable of supervising and directing their children. Doll and McKay (130) gave a social maturity scale to two groups of children of the same mental and chronological ages and found that those in an institution for the feeble-minded tested lower in social quotients than those not in the institution. They concluded that social competence, as well as IQ, must be considered in diagnosing mental deficiency.

Unstable Children

Uhler (295), Oberlin (247), and Glanville (146) reported studies in which they selected children whose intelligence test scores had a wide range of successes and failures. The cases in which scores on verbal and on motor abilities were widely disparate showed marked tendencies toward personality defects and psychoses. Those with higher motor abilities usually were delinquent; those with higher verbal ability usually had personality defects. Oberlin recommended training to bring the poorer ability up to the better as a method of effecting adjustment. Somewhat in keeping with these researches are those of Abrahamson (87) who found that unstable children had poor scores in quality of vocabulary, though not in quantity, and that they tested normally in tests of simple memory and spatial relations, but very low in other tests. Piotrowski (259) found different profiles on the Stanford-Binet for psychotics and nonpsychotics. A psychotic profile on a test should be interpreted as an inadequate measure of the subject's ability.

Summaries of research on exceptional children have been made by Baker and Stullken (97) and by Good (149).

Other Aspects of Mental Development

The following sections are concerned with several aspects of mental development which are not measured specifically by intelligence tests.

These fields are all important in any study of intellectual development, and a number of valuable researches have been reported. Lack of space, however, necessitates only brief treatment of them.

Learning

Retroactive inhibition was studied by Foran (136) and by Lahey (193). Both used lists of twenty-five verbs as the original learning material. Foran used a variety of interpolated tasks and found that inhibition occurred only when the interpolated task was learning nouns, and that there was no relation with age. Some retroactive inhibition was found for the younger children, eight-year-olds, when spelling was interpolated. Lahey found that retroactive inhibition is a function of degree of intelligence and of the length of time devoted to interpolated study. (See Chapter III for a further discussion of these studies.)

Adams (89) compared five methods of serial learning and found fewest errors if the children went back to the beginning after an error. Jenkins (177) had children associate nonsense syllables with nonsense drawings. They used very little visual imagery and the formation of new concepts was important for recall. Eidetic images, when present, did not appear to reduce errors.

Togawa (290), repeating one of Köhler's problems of securing food by means of a stick, found two- to five-year-old children to be inferior to apes, and that understanding seemed to appear in children at about six years. Lambercier and Rey (194) gave a similar problem to four- to eight-year-old children. They found that the direct attack had a strong attraction for the children, and only after failure in this method set up a sufficient negative reaction did the children direct their attention to the detour and indirect way to the goal. Nelson (240) found that children as young as three years of age were able to use a rational method of learning, and that ability increases with age. Maggia (222) trained children in speed exercises, increasing their speed greatly, but after practice the skill lapsed rapidly and was almost gone after two weeks.

Mast (226) gave a learning test to nursery school children, presenting a disturbance in the form of a bell, and motivation in the form of a toy which the child could keep. Those who were disturbed by the noise of the bell took longer, regardless of age. The reward of the toy was, however, stronger than the unpleasant sound of the bell, and all of the children learned the puzzle. Cousinet (120), from observing a four-year-old boy, concluded that children reenact their experiences with monologs in order to understand them; for example, a child acting the part of his mother learns her reasons for praising or blaming him.

Memory

Two studies are reported on changes which occur in remembered material. Hall (161) compared reproduction of diagrams and of pictures

of real objects for immediate and delayed recall, using eleven- and twelve-year-old subjects. The children changed the diagrams to more symmetrical figures; changes in the pictures were influenced by the children's conceptual knowledge. The diagrams were changed after shorter time intervals, and accuracy of recall was related to intelligence and to interest of the material to the child. Northway (246) studied recall for stories and found that children tended to transform unfamiliar names and idioms to familiar ones. (Northway's results with older children are discussed in Chapter III.) Gilbert (144) found that the hedonistic tendency in memory is more evident in adults than in children. Susukita (287) found that as the school year progressed more of the children's memories were of unpleasant things. Boys remembered more pleasant things than girls, and children from higher cultural environments remembered more unpleasant things.

McElwee (214) found that feeble-minded subjects with a mental age of six years were better in a test of visual memory than were normal six-year-olds. Binet mental age correlated .336 with scores on the test.

McGeoch (217) found no reliable evidence of reminiscence in an experiment with five-year-olds after twenty-four-hour intervals. In another study by McGeoch (216) nursery school children were compared with adults in materials of about equal difficulty of learning, with tests of recall immediately and twenty-four hours later. There were no significant age differences, and no tendencies for reminiscence to vary with intelligence, speed of recall, the individual learner, or intentional rehearsal.

Reasoning, Concepts, and Percepts

A large number of studies have been reported on the development of reasoning, judgments, and various concepts and percepts. Berger (105) found development with age in ability to differentiate between objects or ideas in terms of genus, cause, and generalized ideas. City children distinguished more often in terms of values and consequences, while rural children were more likely to make their distinctions by example and description. Blonski (108) asked children to write twenty-five words that occurred to them. Younger children, eight to nine years, wrote mostly names of people they knew; the next older ones named objects of their immediate surroundings; abstract words appeared with puberty. Similar results were found when the children were asked to write on various topics. The development of logical argumentation and proof comes with puberty. Deutsche (129), investigating children's concepts of causal relations, concluded that the adequacy of the answers is related to age, sex and socio-economic status, and that they do not fit into Piaget's classes. Wilson (312) compared five-year-old children and adults in their responses to "action agent" words. The children gave a greater variety of specific concept responses, were more personal, general, and loose, and had more incorrect concepts. When Gozzano (154) presented children with a series of absurd and

logical sentences to explain, the percent of correct responses increased with age and suggestibility decreased with age. Gupta (159) tested children's responses to a story, and concluded that children's reasoning is not a miniature form of the adult's but has the possibilities of growing into adult reasoning. Kaltofen and Simon (182) studied the ability to grasp relationships when material was presented in two different ways. Maier (223) found reasoning ability to develop at about six years of age and to be related to mental age. Rey (267) experimented with tests of prehension with various obstacles and found that the child tends to adapt himself and to coordinate his organization with the environment, utilizing rather than submitting to experience. Pyle (262) scaled reasoning ability in arithmetic problems and reading selections. The latter depended for success more on the difficulty of the thought than on vocabulary. Reasoning was also considered by Muller (239) and Piaget (254).

Stuart (286) studied sensori-motor and conceptual thinking in a battery of tests and found most rapid development between nine and twelve years. He also studied interrelationships between the various aspects of thinking. Wilson and Flemming (313, 314) compared abilities in a variety of tests on first-grade children. Zietz (319) found that children's theories tended to be in terms of mechanical and natural forces rather than anthropomorphic and that they had a tendency to reason in circles. Huang, Chen, and Yang (174) found that neither children nor adults had mysterious conceptions of causality such as Piaget has formulated but based their explanations on previous experience.

Giltay (145) found that two-year-olds can distinguish between one and many, but the first manifestations of analysis and synthesis do not occur until the age of four years. Russell (273), studying children in kindergarten and first and second grade, found that their first concept of number is a "manyness," and that quantity and serial aspects develop later. This is a gradual process. At seven years children have concepts of "most" and "more" but not of "same" and "equal." Szeminska's (289) research showed that children learn arithmetic first by automatisms and do not comprehend the principles involved until later. These are accepted as absolute truth until twelve or thirteen years of age. Other studies in concepts of number are by Morton (236) and Oehl (248). Hildreth (167) studied the success of young children in constructing letters and numbers.

Bandura (98) read children a fairy story with many references to time and found them to be primarily interested in the present with no clear concepts of different time intervals. Mott (237) studied children's concepts through their drawings, Kobayashi (189) by the accuracy of their copies from models, Newhall (243) by orienting visual forms differently and Hsiao (173) by tests of number, time, and spatial perception. Meyer (230) pointed out the bearing of the child's small stature on his perceptions of his environment.

Chemelář (117) studied optical attention to nonsense syllables in children six to eleven years. Although there were wide individual differences, the length of attention periods increased with age. The most frequent attention spans of six-year-olds are from one-half to two minutes. After eight years of age girls have longer spans than boys. Some of the older children could have concentrated for longer than an hour. Gutteridge (160) found that the attention span in free play of two-year-olds averages 9.4 minutes, and for five-year-olds, 23.8 minutes. Other factors related to attention span were found to be sex, intelligence, temperament, home care, health, and the origin of the activity engaged in. Harris (163) worked out a method for studying attention during clinical examinations.

Griffiths (158) studied imagination in five-year-old children by encouraging them to talk freely in a situation in which they drew, looked at ink-blots, told stories, recounted recent dreams, and reported visual imagery with their eyes shut. When the situation was repeated daily for several weeks the children expressed fantasies which were considered to be revealing of intellectual and emotional characteristics.

In the field of children's interests there are few recent studies. Children's wishes, reported by Boynton (109) for Grades I to VI, were most frequently for such material objects as a bicycle, a universal favorite, autos, and clothing, with many very individual wishes. In preferences for form or color Engel (133) found that children under three and a half usually chose on the basis of form; after this there developed a strong predilection for color, 70 percent in the lower primary grades, after which form again became predominant. The largest percent of form reactors were of the highest intelligence group.

Studies of maturity of behavior in children were reported by Hattwick and Sanders (164), Joël (180), and Iwai and Sonohara (175). Keister and Updegraff (184) studied preschool children's reactions to failure. Immature behavior such as asking for help or whining gave way to mature "attempts to solve alone" and persisting interest during a training period. The development of moral judgments was studied by McGrath and Hughes (218) for preschool children, and by Beun (106) for girls eight to nineteen years of age.

Language

Developmental changes of different parts of speech were studied by Goodenough (152) for pronouns, Davis (123) for proper names, and Bain (96) for "self and other" words. Davis (125) also found that distributions in parts of speech change very little between the ages of three and one-half and nine and one-half years. Development in structure of speech is reported by Neuhaus (241), in sentence length by Davis (126), in enunciation and complexity of speech and in erroneous speech sounds by Williams (309, 310). Jersild and Ritzman (178) studied loquacity and vocabulary

in children two to five years of age; the greatest increases were between two and three and one-half years. Loquacity increased more rapidly than vocabulary. Vocabularies were reported by Williams and McFarland (311) and by Uhrbrock (296). Davis (124) compared twins, singletons with siblings, and "only" children, finding the latter to be definitely superior, and the younger twins and twins of lower socio-economic status to be definitely inferior in linguistic development. Other studies are by McGehee (215), Köhler (190), Grau (156), and Lewis (52).

Esthetic Development

In the field of children's esthetics, investigations have for the most part dealt with appreciation, or with the development of skills, in drawing or painting. Only a few of these can be listed here. In appreciation, Körperth-Tippel (191) studied children three to fourteen years of age. The rudiments of esthetic appreciation were present even among the youngest subjects; marked age changes in esthetic orientation were noted at around ten and eleven years. Miller (231) secured preferences for various illustrative technics among children in Grades I to III. In order of preference they rank: first, full color, then red predominant, photographs, blue predominant, wash drawings, line drawings, and black and white pictures. Kubo (192) found developing appreciation among Japanese children for the "rough and subtle" pictures considered by the experts to be good. Both Voss (299) and Körperth-Tippel (191) found that children's appreciation of pictures could be greatly increased by good instruction. Voss (300) extended to lower grades the McAdory Art Test.

Saunders (274) found that artistic ability could be radically changed through training. Tiebout and Meier (293) found that artistic ability is only somewhat related to intelligence. Graewe (155) described the developmental changes in children's drawings of animals. All children reach the stage of a synthetically correct schema, but only those with artistic ability advance beyond this stage. N. Meier (228) presented an interesting case study of an artistically gifted boy who had been blind. Bergemann-Könitzer (104), observing children in free construction of plastic form, found sex and maturity differences at all chronological age levels.

Four studies reported musical ability in young children. Updegraff, Heiliger, and Learned (297) increased both singing ability and interest by training. Colby (119) found that success in learning depended on several factors, and that children had a tendency to simplify a melody, and to persist in familiar patterns when learning a new one. Higginson (166) studied children's affective experience with different musical forms. Musical enjoyment was not closely connected with high associative power of the stimulus. Drexler (131) found increase with age in ability to carry a melody, and a relation between the abilities of mother and child. Young children could sing descending intervals with more ease than ascending intervals.

Baruch (100) concluded from her studies that nursery school and kindergarten children preferred unrhymed verse, and first-graders preferred rhymed verse; however, the differences were not great.

Studying reactions to odors, Peto (253) found that a majority of children under five years were indifferent to, or appeared to like, smells reacted to by adults with disgust. The transition occurs in the fifth and sixth years when the children are obliged to submit to the demands of culture.

Development of Motor Abilities

Several batteries of tests of motor abilities have been presented in the literature during the last few years. These have been used for obtaining a total score, or motor age or motor quotient; and the separate tests have also been compared for intercorrelations and for factors in motor ability. Ozeretzki's tests (250) have been published in French and discussed by Abrahamson and LeGarrec (88). They analyzed these tests into the following elements: static and dynamic coordination of movements, rapidity and precision, simultaneous and alternative movements, and the presence or absence of synkinesis. Correlations between MQ's and IQ's are .31 for girls and .30 for boys. The authors believe that the tests are better adapted for boys.

Wellman (303) described a series of tests for nursery school ages on ascending and descending ladders and stairs; throwing, catching, and bouncing balls; and hopping, skipping, and walking on paths. She reported a retest r of .98 after one week, with r's between tests at a one-month interval of .94, a two-month interval of .93, and a three-month interval of .85. These same tests have been presented in more detail by McCaskill and Wellman (213) with tentative age norms for each item. Correlations between partial scores (where similar types of performance were grouped together) range from .54 to .79 for an age range of two to six years. For more restricted age ranges the r's were somewhat lower, with the exception of the scores for jumping. In most instances there was a significant gain in ability with age. There were small sex differences in certain of the tests, but there was no correlation with ascendance-submission scores.

Several studies have been reported on abilities in more restricted areas. Moore (235) gave norms for ages six to sixteen for an eye-hand coordination test which consisted of dropping marbles into holes in a box. Key (185) devised a scale for scoring nursery school children on the process of learning to dress. She concluded that training was less important than chronological age or maturation. Quinan (263) measured speed of writing in girls between the ages of eight and seventeen and found that speed increases gradually with age.

Age changes in reaction-time were compared by Goodenough (150) for children aged from three and a half years to college students. Improvement occurred both in speed and in voluntary control. A slight sex dif-

ference in favor of males held throughout. Only slight correlation was found with intelligence, with height and weight, and with degree of activity (in the younger children) as observed in the nursery school yard, and none with socio-economic status. Jones (181) also presented data which showed a decrease in reaction time with age for subjects aged from four and one-half to nineteen and one-half years; age changes were most marked before age ten. Motivation in the form of knowledge of results was found to be important; for a single age group scores improved from the first through the fifteenth trial, especially in the first five trials. Pomeroy (260) compared reaction time of children five and one-half years old with adults on five trials a day for five successive days. The children improved their scores, and some of them did as well as some of the adults. Fessard and others (135) gave norms for reaction times for children aged seven to thirteen years. They also found that on the average speed increases with age.

Rhythm—There are reported several studies on rhythmic responses of young children. Leibold (198, 199) observed children three to six years of age for their spontaneously tapped-out rhythms and for their ability to imitate rhythmic tapping. He found the easiest and earliest was a "primitive rhythm"; and other related forms were added to this. Between three and six years there is an increasing ability to adapt to rhythm. The three-year-old's tapping was not imitative but self-expressive, and was the playful moving of the whole body, not in rhythm. Five-year-olds were able to imitate rhythms. Jersild and Bienstock (179) compared children of from two to five years of age with adults, in walking and beating time with their hands to piano music. There was steady improvement from two to five and the adults' scores were twice as high as the children's. There was some relation of this ability to the number of tones a child could sing. Scores increased with increasing tempo, were little affected by the complexity of the music, and not related to the time in which it was played. There was a small increase in score with practice. Wight (307) showed a gain of 18 percent with practice over a period of two months as compared with an increase of 2 percent in a control group. The subjects in this study were ambulatory cases in a convalescent hospital for crippled children. They were tested for speed of tapping and rhythmic tapping. Van Alstyne and Osborne (298) compared Negro with white children, two and a half to six and a half years, on tapping rhythms. The Negroes excelled, especially at the younger ages and for simpler rhythms. They found that a child can maintain a pattern at an earlier age than he can maintain a set pace.

Interrelations of motor abilities—Using tests previously reported upon by Goodenough and Smart (151), Rhodes (268) tested motor abilities of a group of Negro children. Age changes were presented. Intercorrelations between the tests were low and positive. Factor analysis tends to agree with Goodenough and Smart, showing a general ability factor and one "akin to carefulness or attention." Negroes and whites were similar in scores.

McNemar (221) tested the relation of practice to "general" motor ability, and found that the *r*'s indicate a small general factor of motor ability which in some tests tends to increase with practice, but in other tests practice had no effect on their interrelations. Baumgarten (101) classified manual movements.

Relation of motor abilities to other factors—Burckhardt (113) found a group of feeble-minded children to be definitely retarded in their motor functions. Winter (315) found children in a German opportunity school to be inferior to the Russian norms of Ozeretzki's tests. Brody (112) found identical twins to score much more alike than fraternals on the Minnesota spatial relations test. As there could have been little chance for differential practice he concluded that this points to a strong hereditary factor. Durost (132) found age changes in relative skills of the two hands in children in Grades IV to VIII. As they grow older tests involving relatively gross co-ordinations tend toward equalization of the hands, while tests involving a high degree of control tend toward greater differentiation between the hands.

Summary of findings on motor abilities—These recent studies of motor abilities tend to agree in reporting age changes in the abilities measured, although most of the data are for young children; in positive correlations between scores on different tests, although the size of the *r*'s is widely variable among the different abilities compared; in absence of correlation with socio-economic factors; and in improvement with practice on certain skills. Sex differences vary widely according to the specific ability under consideration.

CHAPTER III

Mental Development in Adolescence [1]

FOWLER D. BROOKS

THE MATERIAL on mental development during adolescence is presented under the following headings:

1. Age of cessation and rate of mental development
2. Range of individual differences in intelligence
3. Constancy of IQ
4. Factors in mental development
5. Intelligence of high-school pupils
6. Sex differences
7. Miscellaneous topics
8. Problems needing investigation.

Studies of mental development in adolescence involve, among other things, the following: (a) the selection of subjects for study; (b) the use of measuring instruments and observation technics; (c) retests of individuals at various ages under carefully controlled conditions to determine growth curves; (d) testing individuals typical of each adolescent age, (e) accurate observation and recording of environmental conditions surrounding the subjects used during the period of investigation; and (f) adequate statistical or other analysis. Valid findings are dependent upon the proper execution of each of these details.

Thurstone's criticism (336) of measuring instruments quoted in the *Review* for February 1936 is still in point; improvement is needed in intelligence examinations designed for use after the sixteenth year. The studies reviewed here have employed very nearly the kinds of tests against which Thurstone leveled his criticism. The retest method yields data for plotting individual curves which will reveal laws of mental development only when the measurements and observations are satisfactorily valid and precise. It scarcely needs to be mentioned that no statistical or other analysis can give value to faulty data.

More responsibility for care in selecting subjects for study should rest upon the investigator. Cases selected by convenience may not constitute a typical or random sample; neither can we believe that ignorance of the kind of sample drawn makes it random. Further, many studies of adolescents are inadequate, partial, and seriously limited in their value for throwing light on the mental development of adolescence because they were planned for other purposes.

[1] Bibliography for this chapter begins on page 125.

Age of Cessation and Rate of Mental Growth

Although this problem is not solved with any finality, the accumulating mass of evidence points to an age probably beyond the teens. In the Harvard Growth Study, Dearborn (324) transmuted raw scores into age scores and averaged the results of several different intelligence tests to form a composite mental age. By plotting retest composite mental ages, individual mental age curves were secured. He found some of these showing spurts at various ages after twelve. Mental age curves are not, however, true mental growth curves, because the unit of measurement is not known to be constant (322, 336). That is, a year of mental age at chronological age twelve is not necessarily the same amount as a year at chronological age sixteen.

Freeman (139), using the University of Chicago VACO test, investigated intellectual growth as measured by retests; for the majority of his subjects, the age range covered was from nine to seventeen years. His data seem to warrant the conclusion that intellectual growth does not cease before age seventeen; it continues well beyond that age although with some reduction in rate after age fifteen. Some of the individual growth curves, plotted from the point scores on the test, show positive acceleration, some negative, and some zero acceleration. To throw light on the age of cessation of mental growth in relation to degree of brightness, an analysis was made of the retest data on 122 students from ages eleven to sixteen, divided into three groups—bright, average, and dull. Since these adolescents as a group were above average, the results do not necessarily hold for the general population of adolescents. The "duller" group of these above-average adolescents had not reached the terminus of their mental growth by age sixteen, the highest one used in this comparison. The curves show divergence from ages eleven to thirteen, with those of the brighter ones rising more rapidly; from thirteen to sixteen they tend to be parallel. Freeman pointed out that there is no indication that the slower group is slackening its rate of increase, even at age sixteen. We are inclined to question his conclusion that "the upper group exhibits decreasing increments, whereas the lower group shows almost constant increments of growth" (139:31). Freeman's Figure 7 shows the brighter group making a mean score of 270 to 275 at the age of seventeen. If the maximum score possible on the test is 280 points, then the smaller increments of the brighter group at these later ages may be a function of the arbitrary ceiling set by the test itself.

Range in Individual Differences

Freeman (139) found that the SD of retest scores on the University of Chicago VACO tests increased up to age twelve for boys and to age thirteen for girls and then decreased. The coefficient of variation, the ratio of absolute variability to central tendency, decreased rapidly with age during these years. No distributions are given. It is possible that some of the

decrease in variability is due to the piling up of high scores in the upper ages, and thus depends upon the nature of the test rather than upon fundamental characteristics of mental growth.

Constancy of the IQ

Few studies of the last three years deal with constancy of the IQ during adolescence. The trend in research seems definitely to be toward other problems, probably because the voluminous literature on the subject is deemed reasonably adequate. If markedly different measuring instruments were to appear, the problems of constancy might again become interesting to research workers.

O'Neill (249) reported on the variations in the intelligence quotients of 105 children, but only fourteen of them had a retest at age thirteen or thereafter and the initial tests of all of these were given before age twelve. Accordingly, no conclusions as to constancy of IQ during adolescence can be drawn. Crissey (17) found a general trend of loss of IQ with institutional residence (orphanages and feeble-minded institutions) which he attributes to the effect of the environmental levels of the institutions. In the case of fifty adolescents in two orphanages, average IQ 68, those in one group gained nearly 3 points IQ and those in the other lost more than 4 points IQ from test to retest with the Stanford-Binet. Wellman (302) found correlations between Stanford-Binet IQ at age six years and six months and college entrance examination percentiles at age eighteen years and two months of .07 for 21 individuals who had attended nursery school, and of .48 for 57 individuals who began school in the first grade. For two other similar groups the correlations between Stanford-Binet IQ at age six years and six months and American Council Psychological Examinations as seniors in high school at age fifteen years and ten months, were .48 and .49, respectively.

Lorge and Hollingworth (207) reported on the adult status of twenty-one highly intelligent persons who as children tested 130 IQ or above; all cases were tested with Army Alpha twelve years later and again after one to four years with levels N-Q of CAVD and with tests of general scientific knowledge and general culture. The ages at the last testing ranged from nineteen years and six months to twenty-six years and four months. The probable correlation, free from attenuation, between Stanford-Binet IQ at ages seven to nine years and Army Alpha at ages sixteen to nineteen years was around .85, it being as high as the correlation between Stanford-Binet IQ in childhood and CAVD at maturity. The authors pointed out that the definition of genius as an IQ of 140 or more during childhood needs revision upward, because such individuals are likely to fall anywhere in the upper fourth of the college educated population of the United States when they are at or near maturity. A Stanford-Binet IQ of 180 or more in childhood is more likely to be indicative of "genius" at or near maturity.

Five such children were included in the group studied. All of them at maturity took top rank among their contemporaries. Existing intelligence tests were found inadequate to measure such individuals at ages nineteen to twenty-six years. Other data were presented showing that these superior children continued their superiority through high school and on toward maturity, although the data could not be cast in the customary statistical forms used to express or indicate degree of constancy.

Factors Affecting Mental Growth during Adolescence

To the earlier descriptive studies of mental development in adolescence, we may now add an increasing number which are concerned with the influence of specific factors upon mental growth.

Crissey (121) examined the effect of differing institutional environments upon the mental development of children of the same IQ. This study is one of a series at the Iowa Child Welfare Research Station attacking the problem of factors influencing mental growth from preschool to college. We refer here only to that portion of the study relating to 100 children of ages thirteen years or more. Children in four state institutions were studied—a home for soldiers' orphans, a juvenile home, an institution for feeble-minded, and a hospital for epileptics and school for feeble-minded, all in Iowa. Subjects were selected with a view to obtaining a homogeneous group; no colored children, no epileptics, no children having physical anomalies, and no idiots or low-grade imbeciles were included. The method of matched groups was used. Individuals chosen were within 3 points IQ and within 6 months C. A. at initial test, and the intervals between their test and retest were less than 6 months. The fifty adolescents in the first two institutions had an environmental level much above that in the last two, the feeble-minded institutions. The net change in IQ of the former group was +2.9 points IQ (mean IQ 68.2, range 59-73); of the latter, —4.2 points IQ (mean IQ 68.4, range 62-76); the net difference favoring the first group being 7.1 points IQ. The orphanage groups used in this study represented the lower intelligence levels of the institutional populations from which they were selected, whereas those selected from the feeble-minded institutions were above the average of their institutional populations in intelligence. Crissey concluded that "seemingly, institutional environments of differing mental levels present unlike demands upon children of the same IQ, causing variations in the rate of mental development in accordance with the child's relative placement above or below the mental level of his environment. In other words . . . children develop as the environment demands development" (121:220). The relatively dull moved upward, and the relatively bright showed losses. In another study (17:57) Crissey concluded that "mental level of associates tends to set the pattern of environmental stimulation." These findings should be scrutinized in relation to the tendency for second measures to "regress toward the mean."

Wellman (302) matched children who had attended preschool with primary children who had not attended, on initial IQ and years of attendance after preschool. The preschool children made higher scores on both the American Council Psychological Examinations (taken in the senior year in high school) and on college entrance examinations (taken as freshmen at the State University of Iowa). The critical ratios of the differences were 1.7 and 1.9. She concluded that early favorable environment has a permanent advantage for mental growth.

Intelligence of High-School Pupils

The recent rapid increase in high-school enrolments has led many educators to conclude that the level of intelligence of high-school pupils has fallen because of the influx of persons of lower intelligence. Portenier (330) found a slight decrease in average IQ of high-school freshmen at Lincoln, Nebraska, and in some other cities. However, two other studies are in marked disagreement with that of Portenier's. Roesell (331) compared the intelligence level of pupils in Grades VII to XII of three Minnesota towns in 1920 and in 1934, using the Miller Mental Ability Test, Form A, on both occasions. The population of the towns increased 31 percent during this time, and the high-school enrolment increased 78 percent. The IQ increased in all grades, and the pupils in each grade tended to be younger in 1934 than in 1920.

Rundquist (332) reported data on the intelligence of seniors from all the Minneapolis public high schools, except the vocational ones, using adequate samples (in most schools 90 percent or more). The Minnesota College Aptitude Test was given to 1,559 seniors in 1929, and 1,967 seniors in 1933. The median scores were eleven higher for the boys and six higher for the girls in 1933. Selective migration out of and into the city could account for the difference, but a four-year interval is short for such a factor to produce so marked a difference. Rundquist discussed several possible factors.

Sex Differences

Sex differences in various aspects of mental development during adolescence, such as intelligence, interests, and the like, are reported in studies by Allen (321), Canady (323), Eisenberg (326), Fitzpatrick (327, 328), Freeman (139), Stolz, Jones, and Chaffey (334), Stuart (286), and Symonds (335). Allen (321) reported recent researches on sex differences, giving 121 titles to the literature through 1934. Canady (323) studied sex differences in intelligence as measured by the American Council Psychological Examination in the case of 637 Negro men and 669 Negro women in the freshman classes of 1931 to 1937 at West Virginia State College. No data were given to indicate whether any selective factors might have operated differentially between the sexes. The men

had median and mean scores slightly greater than the women's, with a critical ratio of 1.3. On the five subtests the women excelled on artificial language and analogies, with critical ratios of 4.3 and 0.2. The men surpassed the women on completions, arithmetic, and opposites, the differences yielding critical ratios of 3.8, 6.2, and 0.9.

Eisenberg (326) studied the interests in radio programs of 3,345 children of various intelligence and social levels living in the New York area and found some sex differences in the radio program preferences of adolescents. Fitzpatrick (327, 328) used an elaborate system of testing and retesting 199 students in six classes from fifth-grade elementary science to graduate biology, to ascertain their science interests and also their consistency of response after a fifteen-minute and a three-month interval. Graduate students were no more consistent than fifth-grade pupils. No marked sex differences were found either in supposed interests or in consistency of testimony. The bulk of student testimony gave evidence of being "unstable, inconsistent, ill considered, and unreliable," only 30 percent to 40 percent appearing reasonably consistent and reliable.

Freeman (139) used retest data from the Chicago VACO tests and plotted individual curves. They revealed no significant sex differences. The curves for the two sexes were about the same. Stuart (286), in a study of children between the ages of nine and eighteen years, found consistent sex differences favoring the boys from age twelve and thereafter on Stone reasoning and selective judgment. On the other tests used—logical thinking, perceptual ability, sensori-motor coordination, and handling concrete material—inconsistencies were common. The school children used were from four Iowa cities representing the agricultural county seat type of community and an industrial center. Stolz, Jones, and Chaffey (334), as a part of the California Adolescent Growth Study, have reported on observational data for 100 boys and 100 girls of junior high-school age; they concluded that no one general pattern of development was typical for this age group. One very noticeable fact observed was the preoccupation of these pupils with social activities, arising out of heterosexual interests. Girls showed this social awareness and interest in the opposite sex earlier than the boys.

Symonds' study (335) represents a trend away from the usual studies of sex differences. He studied fifteen areas of human interest by having several hundred high-school pupils, college students, and graduate students in education place items in a rank order as personal problems and also in order of interest for reading and discussion. As personal problems, college men ranked sex, safety, and money significantly higher than did the women. Women ranked mental health and personal attractiveness significantly higher. On interests, men's rankings were significantly higher on health, sex, safety, money, and mental health; women's rankings were reliably higher on interests in personal qualities, family relationships, manners, personal attractiveness, daily schedule, and philosophy. High-

school boys gave higher rankings to personal problems of money, safety, study, daily schedule, civic affairs, and sex; on interests they gave higher ratings to safety, health, money, civic interests, recreation, and study. Among the girls high ratings were assigned to personal attractiveness, manners, and getting along with others. The high-school groups presumably were selected from Tulsa, Oklahoma, and New York City high schools; the college group from Purdue University in Indiana, and the Emporia, Kansas, State Teachers College. If studies of this type are to throw light upon factors affecting mental and personality development at different maturity levels, data should be obtained from the same individuals in successive years, or from groups representing comparable backgrounds.

Miscellaneous Topics

Northway (246) studied the effect of age and social group on children's remembering. She used three groups of ten-, fourteen-, and fifteen-year-old children and found some indication of age differences. The older children remembered a story in its own form more accurately and for a longer time than did the younger ones, who tended to recast the material almost immediately into a form nearer their own interests by omitting or adding parts. If the material was too meaningless, unfamiliar, or difficult for a child, he tended to substitute a story of his own invention, which he stated in terms familiar to him, instead of trying to recall that which was originally given. Unfortunately the study did not include comparable data for age groups above fifteen. Zankov (337) studied the development of memory on 97 boys and 103 girls whose Stanford-Binet IQ averaged approximately 70. He concluded that among morons the development of memory from ages nine to fifteen involves little improvement in rote memory, but shows gains in intelligent voluntary memory and in reproductive logical memory. The data presented show so many irregularities from one age to another that one is inclined to question these conclusions.

Three studies from the Catholic University of America attacked various aspects of retroactive inhibition and gave age data, which unfortunately for our present problem do not go beyond the chronological age of fifteen years. Dries (325) using 672 pupils in Grades IIA to VIIIA concluded that susceptibility to retroactive inhibition bore no relation to age (grade). Pupils in any half year in school did better than those in the immediately preceding half year on original learning, interpolation, and relearning, but showed no apparent increase or decrease in retroaction from Grades IVB to VIIIA. Foran (136) and Lahey (193) used similar methods. Twenty-five verbs from the first 2,500 words of the Thorndike word book were learned in a short period (four minutes). After a few minutes (fifteen to seventeen) they were retested. The control group engaged in physical activities or singing familiar songs. Five types of interpolated activity

were used on the experimental groups—arithmetic problem solving, arithmetic computation, memorizing poetry, memorizing nouns, and spelling and computation. At ages eleven, twelve, and thirteen spelling produced increasing amounts of facilitation. Memorization of other words appeared to have no effect that was related to chronological age. Lahey (193) studied retroactive inhibition as a function of age, intelligence, and the duration of the interpolated activity. This investigation included 3,434 Detroit children. The interpolated activity lasted four, six, eight, ten, twelve, or fourteen minutes with three minutes' testing after each one, the balance of the seventeen-minute period being devoted to group singing. She found that the effect of retroactive inhibition was less as age increased, but that the degree of intelligence was an important factor. Dividing the pupils into three groups—bright, average, and dull—she found that the amount of inhibition decreased as the degree of brightness increased, but if the degree of brightness was held constant the amount of retroactive inhibition decreased as chronological age, and/or mental age, increased.

Johnson (329) compared the scores on the Inglis Tests of English Vocabulary of 656 Anglo-American and Spanish-American high-school students by years for each of the four years. Slight gains were found from grade to grade, but no conclusions can be drawn since neither age nor selection in respect to intelligence is known. Shakow and Goldman (333) reported that for people of the same intelligence level and with a grammar school education those aged twenty to twenty-nine made a slightly better Stanford-Binet vocabulary score than did those aged eighteen to nineteen, but for those having a high-school education the averages were almost identical. Stuart's study (286) of sensori-motor and conceptual thinking showed greater gains from year to year up to the age of twelve than thereafter. No retest data were used, nor is the effect of selection at various age levels known.

Problems Needing Investigation

The most important problems of mental development in adolescence on which information is needed include the following:

1. The preparation of valid and reliable measuring instruments which can be used in the teens and twenties to permit adequate study of development during these years. Such instruments should cover a wide range of mental functions so that any differential aspects of development may be examined.

2. Further study of adolescent mental development by the retest method should be prosecuted to yield data on (a) the rate of mental growth in relation to the degree of intelligence, (b) sex differences in mental development, and (c) the age of cessation of mental development in relation to environmental factors and to the level of intelligence.

3. The preparation of valid and reliable instruments and technics for determining a wide range of adolescent interests.

4. Comprehensive studies of adolescent interests using both the retest and the non-retest methods, with particular attention to changes in interests from year to year, the factors causing such changes, the best means of developing desired interests at these ages, and sex differences in interests and in the changes occurring from year to year.

CHAPTER IV

Physical Growth from Birth to Maturity[1]

HOWARD V. MEREDITH

THE SCOPE OF THIS CHAPTER on physical growth is intentionally restricted in four respects. First, only investigations published during the triennium September 1935 through August 1938 are reviewed. The three-year period ending September 1935 was covered in the *Review of Educational Research* for February 1936 (439). Second, consideration is limited to studies made or published in the United States and Canada. The entire international gamut of research literature on physical growth for the period is too voluminous for even cursory treatment in a single chapter.

Third, attention is confined to researches on subjects which lie within the normal zone of physical build and health. Finally, researches on the growth of the human ovum, embryo, and fetus are not included. For the most part, the age range covered is from birth to the close of the second postnatal decade. The more technical aspects of the studies have been separated out and are presented as Chapter V.

The investigations are systematized for review under the following major headings: growth in external dimensions of the body, change in external body form, factors conditioning growth, dentition, ossification of the skeleton, growth of the internal organs and soft tissues, pubescence, appraisement of physical fitness, and the nature of growth. A bibliography of 165 titles is supplied.

Growth in External Dimensions of the Body

Perlstein and Levinson (451) reported a statistical study of 3,149 birth weight records for infants born at two Illinois hospitals in 1928. They gave only a summary of the results.

> The average birth weight regardless of race or sex was 7.13 pounds (3,234 Gm.). Male children weighed on the average 0.2 pounds (90.7 Gm.) more than female children.
>
> White children weighed on the average 0.25 pounds (113.4 Gm.) more than Negro children. The economic and social status of the parent had no effect on the birth weight of the child. . . . Birth weight increases with the parity of the mother up to the seventh parity, after which it decreases (451: 1645).

An investigation on birth weight, birth length, and the relationship between length and weight of the newborn infant and height and weight of the mother was reported by Gunstad and Treloar (398) based on records accumulated at the Minneapolis General Hospital from 1930 through 1932 for 1,995 male infants and 1,933 female infants for weight and on 435 males

[1] Bibliography for this chapter begins on page 125.

and 427 females for length. The findings were: Pearson product-moment weight correlations between male infants and their mothers .310 and between female infants and their mothers .308, and corresponding correlations coefficients for stature .14 and .20. Swanson, Lennarson, and Adair (480) studied the amount of post-birth loss in weight and the age at which weight at birth was regained for 618 records accumulated at the premature station of the Chicago Lying-In Hospital. A weekly chart for the Dionne quintuplets covering the first ten postnatal months was published by Dafoe (369).

Cates and Goodwin (360) reported central tendency and variability findings, specific for sex, on twelve-day-old infants. A series of 32 measurements was taken on each of 346 male infants and 329 female infants. The infants were all "normal" and did not include cases recorded by the obstetrician as "premature" or "overterm." "The weight of the male child at birth exceeds that of the female by 4 percent. In neither sex has the baby at twelve days quite regained its birth weight. . . . In all dimensions the male baby's measurements are in excess of those of the female; the dimensions in which the female most nearly approximates the male are the pelvic ones" (360:442). Sillman (472) took five measurements on the mandibular gum pads and six on the maxillary pads for each of about 100 infants between the ages of one and eleven postnatal days. A like series of maxillary gum pad measurements was made by Bakwin and Bakwin (342) on palatal casts for 305 males and 123 females ranging in age between birth and one year of age. Lewis (425) studied dental arch growth of children at the Merrill-Palmer School, Detroit, centering attention on growth of the individual case. Bakwin and Bakwin (343) reported a study on growth in 32 external dimensions during the first year of postnatal life. The subjects were 94 males and 104 females born in the Fifth Avenue Hospital, New York City, "supervised from birth in a special clinic," and measured at frequent intervals. They were mainly of North European, Mediterranean, and Jewish stocks and "came from homes of moderate income." Means and standard deviations for each dimension for each sex were calculated at eight age subdivisions of the year. Gesell and Thompson (389) and Thompson (482) published analyses of physical growth data covering the age period from eight to fifty-six postnatal weeks accumulated at the Yale Clinic of Child Development from 219 examinations of 49 male infants and 228 examinations of 58 female infants. All subjects were physically normal, healthy, full-term, single-birth, white infants whose parents were of North European extraction and in the middle range (occupation of father from janitor and machine tender to chemist and die-cutter) for socio-economic status. A study of bodily growth between approximately one month and one year of age, with particular reference to the growth of the individual child, was made by Davenport (371). The subjects were nineteen males and fifteen females, all white, measured at the Normal Child Development Clinic, Columbia University, between July 1933 and June

1937. All were "developing normally" and "the vitamin requirements for growth were satisfied." The total series of observations for each dimension on each child was plotted and smoothed, and a sample series of approximately thirty individual curves, distributed among ten dimensions, presented. It was stated that all individual curves studied showed "an increase in the size of the dimension with age" and rose "concave to the base." Davenport and Drager (373) analyzed the form of individual growth curves extending over the first two years of postnatal life. Individual curves for stature and weight from about twenty infants were employed. It was found that "the points representing the growth from birth to two years cannot be well fitted by a parabola, nor do they lie within any form of a simple logarithmic curve. The best simple curve that we have found that will pass through the points is an exponential curve. . . ." Further, even for equations of the exponential type it was found on reference to observed values that "in the period from five to nine months there is an excess of growth over the theoretical expectation, and during the period from sixteen to twenty-one months a deficiency." These areas of "poor fit" were stated to be clear for stature, weight, and various segments of stature but not to appear in the case of interspinal (anterior iliac) pelvic width.

Bayley (349) reported means for head length and breadth at frequent age intervals from one month to five years, and Meredith and Knott (435, 436) means and variability constants for transverse and anteroposterior diameters of the thorax for stem length (sitting height) and for length of lower extremities (derived as stature minus sitting height) at frequent intervals between three months and six years. An investigation extending over the age period from birth to eighteen years and encompassing 22 anthropometric measurements was reported by Boynton (354). The data gave a total of almost 56,000 values. They were obtained at Iowa City, Iowa, from measurement of over 1,200 white girls, predominantly representing the professional and managerial classes. Tabular and graphic analysis, derived from 28 age groupings for each dimension, covered central tendency, variability, mean growth trends, percent rates of growth (calculated from successive means for a given dimension), and individual curves for stature.

> The curves for stature, sitting height, and bi-iliac and bi-deltoid diameters show four phases of alternating rapid and slow growth. They indicate a rapid increase in mean magnitude during infancy; a slow, regular growth throughout childhood; a second period of rapid increase before ten to eleven years; and a final interval of slow growth during adolescence and early maturity . . . (354: 95).

Individual curves for stature indicate that:

> The T-score technique can be used to predict stature of girls at eight and nine years from observed statute at six years. . . . Adolescent acceleration begins over a period of five years, and the age when maximum adolescent stature is attained covers a range of three years (354: 98).

Meredith (441) published a paper on prediction of stature for males

seven to eleven years of age. The data were accumulated by the Harvard Growth Study on 263 males drawn from the elementary-school population of three small towns in the vicinity of Boston, Massachusetts. The stature of each body at eleven years of age was predicted from his measured stature at seven years by the T-score method. On comparison of the predicted with the measured values for eleven years, it was found that the mean error of prediction, signs being disregarded, was 1.07 cm. "Ninety-five percent of the predictions over this four-year span were not in error more than $\pm$ 2.5 cm. The maximum error of prediction was 3.7 cm" (441: 283). A quantitative description of "the growth of Iowa City white children with respect to circumference of arm, forearm, thigh, and leg during the period from birth to eighteen years" was made by Meredith and Boynton (442). The data were accumulated between 1930 and 1935 from measurement of 1,013 males and 771 females. They found that "individual differences are marked. Some males and females in the samplings at six years of age have larger girths of both upper and lower limbs than have some males and females at eighteen years" (442: 402).

Following an exhaustive and exemplary critical analysis of the research literature on the surface area of the body, Boyd (352) synthesized the comparable data at successive ages for both the prenatal and postnatal periods of life. For the postnatal period, she pooled 109 measurements of the surface area of the body and its parts "for which the lines of demarcation between the parts were approximately the same" (352: 119). From these (a) curves were obtained "drawn in by inspection to the weighted medians of surface area," and (b) values were read from these curves for "age increases in the surface area of the head, trunk, upper extremities, and lower extremities. . . ."

> The growth in surface area of the total body or any of its parts may be represented by two asymmetrical signoid curves, the first or circumnatal curve extending through the prenatal period to about three years with its inflection point at birth, the second or adolescent curve extending from three to twenty years with its inflection point about puberty (352: 119).
>
> Throughout the developmental period of life the pattern and rates of growth in surface area of the body and its parts maintain an intermediate position between those of height and weight (352: 133).

Changes in 22 dimensions of the head and face between three years of age and senility were studied by Goldstein (392). The subjects were 500 Hebrew males, fifty at each biannual interval from three to twenty-one years. ". . . as a whole, the head is already four-fifths or more of its maximum size at three years. . . . The face too is largely completed in size at three years, manifesting some 70 percent of its total increment at this time" (392:58, 60). Rittershofer (460) took 67 dimensions of the face—including lengths, widths, depths, and angles—on "57 Filipino skulls and 100 mandibles. . . ." A comparative study of head height, measured at auricular floor to bregma, porion to vertex, and porion to bregma, was reported by Goldstein (394), taken on Jewish males between the ages of three and

twenty-one years, and on non-Jewish white children between three and twelve years. Boas (351) reported an analysis of individual stature curves for Hebrew and non-Hebrew girls in attendance at Horace Mann School, New York, from approximately six to seventeen years. "When the material is so arranged that those children are grouped together who have the maximum rate of growth at the same age . . . the intensity of growth during the years of adolescence is the less, the later the maximum rate occurs. . . . At the same time it seems that the more or less rapid rate of development does not influence the final stature" (351: 920).

An analysis of approximately 8,000 annual increments in body weight for elementary-school children between the ages of six and fourteen years was published by Palmer, Kawakami, and Reed (448). The data were derived from weighings of some 2,500 white children in the public schools at Hagerstown, Maryland, during the years 1921-27. Analysis, specific throughout for sex and year of age, yielded means for observed weight, means and standard deviations for annual gain in weight, and means for standard deviations for annual gain in weight of four-pound subgroups according to weight at the beginning of the year. Wilson (501) analyzed seriatim data for height and weight accumulated by the Harvard Growth Study from annual examination of 275 public school girls at each year of age from seven to sixteen.

1. The coefficient of variation increased from seven to twelve years—from 4.9 to 5.4 for height and 14.6 to 21.3 weight—and then decreased to sixteen years (4.0 height and 16.6 weight).
2. Coefficients of correlation for height with weight decreased from .77 at seven years, through .71 at eleven and twelve years, to .42 at sixteen years.
3. The correlation of height at seven with height at sixteen years was .81, implying that the variance in the height at age sixteen was 66 percent "controlled" by a knowledge of the height at age seven.

Means for height and weight of private school boys and girls at each year of age from six to seventeen were reported by Richey (458). The data were taken from the permanent records of the Laboratory Schools of the University of Chicago. They represented nude measurements on more than 3,500 non-Jewish, white children "from well-to-do and professional classes." Girls were lighter than boys at six and seven years, heavier at eight to fifteen years, and lighter at sixteen and seventeen years. They gave means exactly eight pounds higher at thirteen years and 13.8 pounds lower at seventeen years. Gray (396) investigated the size of eighteen dimensions of the body on 109 men (mean age twenty years) of the varsity and freshman football squads at the University of Chicago in 1929.

Two hundred college women (mean age 19.9 years) of Louisiana, whose parents and grandparents were of southern origin, were measured by Gould (395) during the years 1930-1933. A series of about 20 measurements were taken and observations for hair and eye color were made. "The outstanding result of this regional study of 'Old Americans' women is the evidence of close correspondence, in average physical measurements

and morphological characters, with similar groups from other parts of the United States. There is very little suggestion of a development, through geographical isolation, of a 'southern type' of American women" (395: 78). The variability of several dimensions of the mandible in "United States adult whites" was studied by Hrdlicka (409) on mandible specimens for 57 males and 32 females. Means for measurements on young adult women were reported by Gunstad and Treloar (398) and by Cates and Goodwin (360). Goldstein (392) and Rittershofer (460) studied changes in facial dimensions between early maturity and senility. Hrdlicka (407) reviewed investigations on growth during adult life relating to stature, head and face, body stem and limbs, thorax, and hand and foot.

Change in External Body Form

Changes in body proportions during infancy were investigated by Bakwin and Bakwin (342, 343, 347), Cates and Goodwin (360), Davenport (371), Gesell and Thompson (389), and Thompson (482).

Bakwin and Bakwin (342) obtained means at nine age subdivisions between birth and one year for three palatal indexes. "Asymmetrical palates are not infrequently seen in infants, even during the newborn period. They are regularly associated with asymmetry of the head" (342: 1023). From a study of 32 measurements of the body during the first postnatal year, Bakwin and Bakwin (343) reported the following changes in body form: "The face at birth is broad . . . the nose is broad and short and the bridge depressed. At one year the face is relatively narrower, the nose longer and narrower and the eyes smaller and closer together . . . The lower extremities grow more rapidly in length than the remainder of the body" (343: 182).

Cates and Goodwin (360) reported mean ratios for twelve-day-old infants. Gesell and Thompson (389) and Thompson (482) reported findings for fifteen indexes covering the postnatal age period from eight to fifty-six weeks. At one year of age, it was found that stature consisted of approximately 25 percent head and neck length, 33 percent trunk length, and 42 percent pubes-soles length.

Studies on change in body proportions during infancy and the preschool years were reported by Bayley (349), Knott and Meredith (422), and Meredith and Knott (435). Bayley (349) studied growth changes in the cephalic index during the period from one month following birth to five years of age. The subjects were 31 males and 30 females, each examined, with occasional exceptions, at 18 successive ages. "The children at birth are relatively dolichocephalic, rapidly becoming brachycephalic until about seven months of age. After ten months the tendency is toward increasing dolichocephaly" (349: 6). The cephalic indexes obtained at one month correlated .51 with those obtained at two years. However, "when the age interval is short, the correlation tends to be high, especially after twelve months . . ." (349: 13). "When the individual curves are plotted for each

child the curves are found to vary widely in their tendency to change, ranging from the curve of one child whose increment from the lowest to the highest index is only two points to one whose increment is sixteen points, with the majority exhibiting curves similar to the mean of the group" (349: 14). Meredith and Knott (435) investigated the trend for the thoracic index "computed as the percentage relation of chest breadth to chest depth. . . . There is an increase in mean thoracic index for both sexes during the age period from three months to five years."

Developmental trends extending from birth to six years of age were presented by Knott and Meredith (422) for the following proportions: bi-iliac/bi-deltoid, bi-iliac/transverse thorax, bi-iliac/stem length, and bi-iliac/leg length (derived as stature minus sitting height). The subjects and observations were approximately the same as for the study immediately preceding.

Broadbent (356) described changes in the contour of the face between birth and adulthood as revealed by seriatim roentgenograms accumulated by the Bolton study of development of the face of the growing child, and gave numerous illustrations of the normal sequence of change in facial form as indicated by roentgenographic tracings superimposed in terms of the Boltonnasion place of orientation and its registration point. Vollmer (492) reported having been interested in measuring, rating, and photographing various characters of the external ear over a period of fourteen years. In discussing the problem of "whether or not the ear of the newly born infant is subject to changes during growth and development which modify fundamentally its original form and appearance," he stated the finding that "regular changes of form do occur" (492: 579).

Postnatal changes in the proportion of body surface area allocated to the head region, trunk region, and regions of the upper and lower extremities were studied by Boyd (352). Surface area of the head decreased from approximately 21 percent of the total surface area of the body at birth; through 13 percent and 10 percent at five and twelve years of age, respectively; to 8 percent at eighteen years. Surface area of the lower extremities increased from roughly 30 percent at birth; through 34 percent at five years and 37 percent at twelve years; to 39 percent at eighteen years. Meredith and Boynton (442) studied sex differences and changes with age for ten ratios of means covering the proportional relations between limb girths, and for limb girths referred to selected limb breadths and to stature. The trend of the skelic index between three months and eighteen years of age was studied by Meredith and Knott (436). This index, determined on over 8,000 paired measurements, was defined as the percent relation of length of lower extremities (stature minus sitting height) to stem length (sitting height). There was a steady rise in mean skelic index from three months following birth to thirteen years for females and fourteen years for males, and a slight but consistent fall in mean index following these ages. The mean length of the lower extremities increased from less

than one-half of stem length at three months to more than 90 percent of stem length at eleven years.

Goldstein (392) investigated changes in the form of the face between three years of age and senility. He employed both the index approach and the approach of comparing facial profiles for successive ages. The subjects were fifty Jewish males at each of eleven ages. "Profile projections of the face indicate considerable growth outward and downward between three and twenty-one years, more so in the lower than in the upper part" (392:86). Irwin (410) studied changes in the form of the foot between the ages of six and eighteen years. Footprints were taken on 323 boys and 353 girls. From these, values for degree of flat-footedness were derived by means of a specially devised footprint index. Means showed "no apparent tendency toward flat-footedness with increasing age . . ." (410:50). Two papers by Davenport (372, 375) incorporated findings for the intermembral index, the brachial index, and nose height in relation to face height. Studies on the body form of college students were reported by Gould (395), Gray (396), and Pryor, Shepard, and Moody (455). The latter calculated the index bi-iliac diameter/stature on 2,061 males and 1,827 females measured at three California institutions and ranging in age between seventeen and twenty-four years. Gould (395) took observations on the contour of the nose and obtained means for five indexes on 200 women of Newcomb College of Tulane University, New Orleans, whose parents and grandparents were all of southern origin.

Factors Conditioning Bodily Growth

Prematurity

Studies on premature infants were made by Dafoe (369), Dunham and McAlenney (381), Swanson, Lennarson, and Adair (480), and Wilcox (500). Wilcox studied infants born at the Sloane Hospital for Women, New York City, between 1929 and 1934. "During this time there were 10,163 consecutive births to mothers in the public wards. Three hundred and thirty, or 3.24 percent, of the infants weighed 2,500 grams or less at birth and on this basis were regarded as premature" (500:848). Roughly 70 percent of the cases weighing less than 1,500 grams at birth and 13 percent of those whose weight was between 1,500 and 2,500 grams died before leaving the hospital. Findings were considered to confirm the "well-recognized tendency of small infants to 'catch up' and approach the average weight curve of mature infants" (500:861).

Birth Order, Multiple Pregnancy, Factors Associated with Birth

The effect of "ordinal position in the birth sequence and the age of the mother upon . . . birth weight of infant" was studied by Goldstein (390). Composite means for the total series were 3,332 grams for birth weight,

26.2 years for mother's age, and 278 days for duration of pregnancy. Birth order means were 3,194 grams for 228 first-born cases, 3,368 grams for 287 second-born, 3,448 grams for 167 third-born, and 3,417 grams for 68 fourth-born. Perlstein and Levinson (451:1645), from an analysis of 73,149 birth weight records for infants born in Illinois, reported the findings:

1. Birth weight increases with the parity of the mother up to the seventh parity, after which it decreases.
2. Birth weight increases with maternal age, older mothers giving birth to heavier children than younger mothers.

Newman, Freeman, and Holzinger (244) compared identical and fraternal twins for stature, sitting height, weight, head length, and head breadth. The subjects were fifty pairs of identical twins, reared together, and fifty-two pairs of fraternal twins, each pair of the same sex, between the ages of eight and eighteen years. Correlation coefficients, age partialed out, were .93 identicals and .64 fraternals for stature, .92 identicals and .63 fraternals for weight, .91 identicals and .58 fraternals for head length, .88 identicals and .50 fraternals for sitting height. Supplementary comparison was made between the fifty pairs of identical twins reared together and nineteen pairs of identical twins separated in infancy and reared apart. It was found that for stature and the head measurements separated twins were "approximately as much alike as are unseparated identical twins. In weight . . . as different as are fraternals" (244:357). Consequences either of the birth process itself or of the metabolic changes associated with the transition from intrauterine to extrauterine life were investigated by Schour (468) for calcification of the deciduous teeth and by Sontag (474) for calcification of the tarsal bones. Schour's data (468) included 100 deciduous teeth in ground sections and serial sections of the dentitions of two full-term infants. For the former he found that "lines were present in both the enamel and the dentin when ground sections were prepared." He concluded: "The neonatal lines constitute a permanent biologic landmark which can be used for the determination of the amount and quality of the enamel and dentin laid down before and after birth" (468:1954). Sontag (474:1254-55) examined 98 lateral roentgenograms of the tarsal bones taken on infants at one month following birth. Fifty-four were found to show "a fine white line a fraction of a millimeter in width which follows the periphery of the talus or of the calcaneus . . . The band which forms the periphery of the bone at one month is never present at birth . . . the striae and the thickened temporary zones of calcification are merely different phases of the same process. . . ." As possible causes of the interruption in osseous growth at birth Sontag suggested ". . . the shock of birth itself. . . . The neonatal loss of fluid and the assumption of function by the gastro-intestinal tract . . . the endocrine readjustment which probably occurs at birth, when the mother's endocrine system ceases to be a factor in the endocrine balance of the infant." Commenting on the fact that disturbed growth was not evident for

the entire 98 cases, he stated: "It must be remembered that both the severity of the birth process and the infants' ability to withstand it may differ greatly from infant to infant."

Race

Investigations on the growth of children of diverse racial stocks were reported by Beckham (350), Dunham and others (380), Ito (411), Preston (453), Royster (463), Steggerda and Densen (476), and Ting-an Li (483). The basic material analyzed by Ito (411) consisted of seventeen anthropometric measurements for each of 202 full-term infants, 94 males and 108 females, born in California of Japanese parents during the period 1932-1935. Ting-an Li (483) reported a mean birth weight of 3,037 grams for 1,148 full-term liveborn, single-birth Chinese infants of healthy mothers born at the Peiping Union Medical College Hospital during the eight-year period prior to 1930.

In the winter of 1931 Preston (453) examined children five to fourteen years of age of two racial groups living in San Francisco. Her sample consisted of 740 American-born children of Japanese parents from the south-central part of Japan, 346 males and 394 females; and 391 Chinese children, 188 males and 203 females, of Cantonese extraction. Measurements of stature, weight, and bi-iliac diameter were taken on both groups, and measurements of thickness of skin and subcutaneous tissue.

Steggerda and Densen (476) analyzed data for stature and weight on 3,332 Navajo Indian children six to eighteen years of age, and for 3,730 Dutch white children six to fifteen years of age. ". . . data for the Indian children were collected from schools in the Navajo reservation in New Mexico and Arizona . . . care was taken to select those children who were relatively pure Navajo . . . The data for the Dutch white children were collected in the schools of Holland, Michigan, and only those whose ancestors came from the Netherlands were used . . ." (476:115).

A study of the stature and weight of 219 Pueblo Indian children, 103 males and 116 females, age seven to eleven years, was made in the summer and fall of 1934 by Dunham and others (380). The children lived under poor conditions, such as crowded sleeping rooms, lack of sanitary arrangements, and inadequate diet.

Royster (463) analyzed measurements for bi-iliac diameter on 9,700 Negro children six to fifteen years of age measured in Virginia. Beckham (350) analyzed data for height and weight taken on approximately 1,000 city Negro children twelve to sixteen years of age measured at Chicago, New York, and Washington, D. C.

Geographic Area, Season of Year, Decade

A comparative study of stature and weight for school children in rural and in urban areas of Utah was reported by Brown (357). Urban subjects

numbered 6,996 males and 6,875 females and rural subjects numbered 7,039 males and 5,874 females. The term "rural" was used to include "that part of the population residing outside of incorporated places having more than 2,500 inhabitants." In general, urban children were found to be larger than rural children. "Up to and including the tenth year mean heights of rural and urban boys differ less than one inch; from eleven to fifteen years the differences are slightly above one inch. At six years mean weights differ not at all; from seven to ten years, inclusive, the differences vary from 1.1 to 1.5 pounds; thereafter, the differences are 3 pounds or more" (357:4). For stature and weight the differences are statistically significant at each age from eight to fifteen years. Gafafer (387) compared physically defective school children of three regions of the United States in terms of means for seven anthropometric measurements and four ratios. The regions represented were the Northeast (six states), the North Central (five states), and the South Central (six states). The children ranged in age between six and fourteen years, were native-born of white native-born parents and grandparents, and had such physical defects recorded against them as "carious teeth, defective tonsils and adenoids, goiter, enlarged cervical and submaxillary glands, and defective vision . . . The methodology employed disclosed no evidence that the differences in geographic location of the children with recorded physical defects influences their physical growth, rate of physical growth, or body form." The roles of both geographic and time variations in body growth were discussed by Mills (444:53,56). Stature and weight data on college women were stated to indicate that "greatest size and robustness of form tend to come where the climate is stimulating and heat loss from the body is readily accomplished . . ." Additional research was cited in support of the viewpoint that human beings "living under conditions of moist heat grow less well and assume distinctly more slender body form," and that even "adequacy of diet cannot overcome the physical retardation that comes with difficulty of body heat loss . . . There are several indications that human advance comes in long undulations of progress and recession, and that these waves are truly biologic and based on some extraterrestrial force affecting man." In support of this time cycle hypothesis attention is called to the increase in stature from prehistoric man to such early civilized groups as the ancient Egyptians, Greeks, and Indians of the Southwest, to the decline in stature to the Middle Ages, and the worldwide quickening of growth during the last half-century. Chenoweth (361) studied the change in mean stature and weight of college freshmen at the University of Cincinnati over a period of twenty years. Averages for the five-year period 1916-1920 compared with those for 1931-1935 showed a gain in stature of 1.1 in. for males and 0.9 for females, a gain in weight of 9.3 lb. for males and 2.2 lb. for females, and a reduction in age at entrance of one-half year for males and one-fifth year for females.

Investigations on seasonal variation in growth were made by Frazier (386), Marshall (434), Perlstein and Levinson (451), Ting-an Li (483),

Turner and Nordstrom (490), and Whitacre (499). Perlstein and Levinson (451) analyzed birth weight data for 3,149 infants born at two Illinois hospitals in 1928 and found that "children born during the warm months of the year have a tendency to be slightly heavier than children born during the cold months." Means from birth weight data distributed by month and season of the year were reported by Ting-an Li (483). The subjects were 1,938 Chinese infants born at the Peiping Union Medical College Hospital between 1922 and 1930. It was stated that (a) the sample was "fairly even in all months" with respect to "mother's age, nativity of mother, sex, and order of birth . . . " and (b) "the Peiping weather is quite similar to that of Boston, except that the former is not so humid as that of the latter." Means by month of year gave a minimum for February (2,907 grams) and a maximum for July (3,185 grams). Means by season were lowest for the winter months December, January, and February (2,945 grams) and highest for the summer months July, August, and September (3,110 grams). These mean differences of 278 grams by month and 165 grams by season were both statistically significant. It was concluded that "there exists a real difference in birth weight with respect to season." Turner and Nordstrom (490) weighed 1,612 males and 1,617 females, five through twelve years of age, at the public schools of Malden, Massachusetts. The percents of pupils failing to gain for three successive months more than doubled from October to May. As factors possibly contributing to the finding, sunlight, climate, activity, clothes, food, and colds were mentioned. An extensive and carefully executed study on seasonal variation of growth in stature, sitting height, and weight was published by Whitacre (499). The subjects were Texas school children—981 white, 830 Mexican, and 731 Negro—in attendance at three San Antonio public schools.

1. For all three races, fall was slightly the best season for gaining in weight. The monthly gain in the four fall months, October to January, averaged about 10 percent of the entire yearly gain.
2. Among the three races, October was conspicuous for consistently excellent gains (from 11.3 percent to 16.1 percent of the yearly gain), and April, for uniformly poor gains (from 1.4 percent to 6.4 percent of the yearly gain).
3. Average monthly gains in standing and sitting heights for the three races showed negligible differences between spring-to-fall and fall-to-spring periods. In contrast, weight gains over the same periods were consistently greater in fall-to-spring than in spring-to-fall periods.

Monthly weight records for 139 Mississippi school children covering the entire school term of nine months were analyzed by Frazier (386). "These showed an average gain of 1.08 pounds from October through January and a mean gain of 0.36 pound from February through May, inclusive." Marshall (434) reviewed American research on seasonal variation in stature and body weight. Findings for infants, preschool children, and children of school age were synthesized separately. For stature, of the nine studies examined only two (of school children) gave any indication of seasonal

variation. For weight, on the other hand, of the nineteen studies examined more than half indicated greater gains in the fall than in the spring.

Diet

Studies on the effectiveness of various prelacteal and complementary feedings in reducing the initial weight loss of the newborn infant were reported by Crawford (366), Dolce (379), Epstein and Thompson (382), and Quillian (457). Crawford (366) compared results from use of two hydrating solutions with infants born at the Pennsylvania Hospital. It was found that the initial weight loss for the group receiving the gelatin hydrating solution "was only one-third that of the control group and less than half that of the group fed lactose citrate, and the weight at discharge was 1 ounce (28.35 Gm.) above the weight at birth as compared with 3 ounces (85.05 Gm.) less than the weight at birth of the control group and a return to the weight at birth of the group fed lactose citrate." Quillian (457) made a study of the effect of two different diets on 100 neonates born during a six-month period (1935) at the Jackson Memorial Hospital, Miami. Quillian concluded: "Among the infants considered there seems little advantage of one method over the other. . . . One feels that much of the value of both procedures lies in the administration of more fluids at a time when the breast supply is least" (457:764). Epstein and Thompson (382) compared results for 400 infants born at the Wesley Memorial Hospital, Chicago, using alpha and beta lactose as the experimental variable. Seventy percent of the alpha group and 82 percent of the beta group regained birth weight by the ninth day. Dolce (379) studied forty-eight normal-birth infants selected at random from among the neonatals of Columbus Hospital, Buffalo, "to determine the value of an A and D vitamin nutritional supplement in reducing the weight loss in the first ten days of life." The cod-liver oil supplement was begun the day of birth and administered three times daily as a drop directly on the tongue; the daily dosage was 3,420 U. S. P. units of vitamin A and 484 units of vitamin D. The oil anointment supplement was a blend of oil with an antiseptic and enriched with vitamins A and D, standardized to contain 612 U. S. P. units of vitamin D per ounce. Two anointments of three teaspoonfuls were given daily without removal of the adhering oil. By the tenth day following birth, 56 percent of the control group, 85 percent of the oil anointment group, and 100 percent of the cod-liver oil concentrate group were found to either equal or exceed their respective weights at birth. Mean gains between birth and the tenth day were 1.7 oz. for the control group, 5.5 oz. for the oil anointment group, and 6.3 oz. for the cod-liver oil concentrate group. The results were considered to give weight to the value of dermal absorption of vitamins.

The relationship between vitamin D intake and stature growth of infants during the first postnatal year was investigated by Slyker and others (473) and by Stearns, Jeans, and Vandecar (475). Stearns and others pre-

sented two central tendency curves for length (stature) of male infants. One was drawn to averages from thirty-six cases given the equivalent of one teaspoonful of cod-liver oil daily (340 to 400 U. S. P. units of vitamin D), and the other to averages from 11 cases fed irradiated milk or its vitamin D equivalent (60 to 135 U. S. P. units of vitamin D daily) as cod-liver oil or cod-liver oil concentrate milk. When compared with stature averages from Kronfeld, 1929, and Stuart, 1934, the latter curve was found to give almost identical results and the former curve to give increasingly higher results with age.

The accelerated rate of growth found for the high vitamin D group, particularly during the latter half of the first year, was ascribed "chiefly to the increased intake of vitamin D," which, "through its effect of mineral retentions, increases the amount of calcium salts available for the formation of new bone." This claim was supported by the finding that, where milk intakes were the same, "the average quantities of calcium and phosphorus actually retained daily by the infants given one teaspoonful of cod-liver oil a day were significantly greater than the mean daily retentions of calcium and phosphorus by infants given the moderate intake of vitamin D" (475:5). Slyker and others (473) reported that over a three-year period the research laboratory of the Children's Fund of Michigan, cooperating with the Children's Hospital of Michigan, had accumulated data on vitamin D intake and stature growth for 414 infants followed from approximately one month to one year of age. The average gain in stature obtained between one month and one year of age was approximately 21.4 cm. for the group receiving the highest vitamin D dosage, 20.0 cm. for the moderate vitamin D intake group, and 18.9 cm. for the group supplied with almost no vitamin D.

Joslin and Helms (415) studied the effect of increased vitamin B on growth during the first postnatal year in several anthropometric dimensions. The effect of an increased amount of vitamin B (B_1), in the form of a water extract of rice polishings, was studied by Poole and others (452). They used 117 normal, full-term infants living in their own homes and examined monthly from approximately one month to one year of age. "The average estimated vitamin B_1 content of the supplemented formula was approximately 230 Sherman-Chase units. . . . In general, the group receiving the supplement of the extract of rice polishings . . . gained weight more consistently and with less variation than the group without this added nutrient. . . . We believe that vitamin B has a stabilizing effect on growth and nutrition . . . an increase of from 30 to 50 percent in the vitamin B intake did not produce a significant difference in the average rates of growth in weight for these two groups of healthy babies."

Investigations on the relationship between diet and tooth decay were made by Jay and others (412:849-51) and by Tisdall (484). Jay and others reported two findings derived from data accumulated at a children's home near Ann Arbor over a period of approximately ten years. "From 75 to 80 percent of the children had no new caries over a period of several years,"

and "positive acidophilus cultures were comparatively rare." This unusually low level of caries activity was considered disconcerting since the diet at the institution appeared inadequate for the prevention of caries. "Sugar was never served at the table and candy was forbidden as a general policy." The administration of "an abundance of candy daily for five months" to 44 children showing no caries activity during the previous twelve months resulted in increased acidophilus counts for 80 percent of the cases and the development of active caries for 43 percent of the cases. A study "planned to show whether lack of vitamin D had any effect on development of tooth decay" was reported by Tisdall (484). One hundred and sixty-two children in a Canadian institution were observed over a period of one year. The diet supplied all food elements ordinarily considered necessary with the exception of vitamin D. For 87 children vitamin D was added to the diet daily through its incorporation in a small biscuit. From dental examinations made at the beginning and end of the year the incidence of new caries was found to be .46 for the control group and .22 for the vitamin D group.

Frazier (386) compared gains in weight over a six-month period for 368 Mississippi school children receiving a relatively adequate school lunch and a control group of 363 children. On the one hand the author acknowledged that the differences in gain for the two groups did not show a consistent relationship from age to age and that the total mean advantage for the experimental group was slight. On the other hand, she insisted that the findings supported the concept of a planned diet, such as was used, resulting in increased weight gains. Roberts and her associates (461, 462) reported studies of the effect of milk supplements on the stature, weight, and carpal bone growth of institution children of grade school age. The studies were "undertaken in an attempt to determine (a) whether the daily addition of a pint of milk to the diets of children already receiving approximately one pint would produce any measurable improvement in physical status in a year, and (b) whether any advantage could be determined for irradiated over nonirradiated milk." Trios, matched for age, sex, deviation from average weight for stature and age, and condition of teeth, were followed throughout a calendar year—November 1934 to November 1935. For 36 trios, Roberts and others (462) found the two supplement groups to exceed the control group for stature and weight. "The average excess in mean gain in height was 0.9 cm. (0.3 inch) for both milk groups, and in weight was 1.03 kg. (2.27 pounds) for the plain milk and 0.62 kg. (1.4 pounds) for the irradiated milk group." For 24 trios, Roberts and MacNair (461) found the mean gain in Carter ossification ratio points "was 6.0 for the control, 8.3 for milk and 8.2 for the D-milk group, an advantage of 2.3 and 2.2 points, approximately a third of a year's quota, in favor of the supplemented groups. The control group gained 79 percent of its expected quota; the supplemented groups each 115 percent."

Physical Defects, Illness, Economic Depression, Health Care

A study of "the relation between physical defects in school children and their physical growth" was made by Gafafer (388). The data were accumulated in twenty-one states on 28,317 white children of native-born parents and grandparents. The age range of the children was six to fourteen years. For the most part, they lived in large urban areas. None was seriously ill, since all were attending school, and grossly defective or crippled children were excluded. Defects such as carious teeth, defective tonsils or adenoids, goiter, poor vision, and enlarged cervical or submaxillary glands were recorded for 12,717 cases. The remaining 15,600 constituted the nondefective group. Seven physical measurements were taken and four indexes computed on the children of each group. In general, central tendency curves for the nondefective group, drawn to means at successive one-year intervals, were slightly above corresponding curves for the defective group in weight, vital capacity, stature, and sitting height, while the trends tended to show the reverse relationship for thoracic girth, width, and depth. Increment curves for each sex of each group, derived from differences between pairs of means for a given measurement at successive ages, showed no consistent differences between the nondefective and the defective groups. Both in description and graphic illustration of findings, Gafafer tended to emphasize the anthropometric superiorities of the nondefective group and minimize those of the defective group. Hardy (400) and Palmer (449) investigated the relationship between illness in childhood and physical growth, body build, and size of maturity. On approximately 400 children in the public schools of Joliet, Illinois, a series of eighteen measurements was taken at regular intervals from seven to twelve years of age, and more than 50 percent of the subjects were remeasured at about twenty years of age. In addition, cumulative health histories were obtained. "These health histories are believed to present a reasonably accurate account of all serious and prolonged illnesses during the infancy and childhood periods." Incidence of illness ranged from one to sixteen episodes per child, exclusive of colds and rickets, with 13 percent, the "frequently ill," having nine or more illnesses; and 14 percent, the "infrequently ill," having three or fewer illnesses.

> Detailed analyses of the growth records revealed no reliable differences between the two groups (frequently ill and infrequently ill) in any one of the following dimensions, stature, leg length, shoulder width, hip width, chest girth, lung capacity, strength of grip, weight. . . . In more than half of the findings the frequently ill children, on the average, made the larger gains, although all the observed variations were well within the range of chance (400:247-48). From our findings we are forced to conclude that in the case of most children in ordinary home conditions, the effect of illnesses will be temporary and no permanent influences of the general patterns and results of physical growth are likely to remain (400:258).

Palmer (449) reported a preliminary study on the relation of body build to sickness. The analysis consisted of correlation tables of height and weight

to which is added, in each cell of the correlation table, a calculation of the average number of days absent from school because of sickness. Inspection of the tables "indicates that there is no practically significant association between height and weight and illness." Todd (488), in a discussion of mineralization of the skeleton, stated:

> Children of impoverished constitution, whether from prolonged toxemia, protracted ill health or inability to utilize mineral, show a pronounced reduction of the labile mineral with encroachments even on the trabeculae themselves which become thinner or fragmented (488:160-61). Correct therapeusis for depleted mineral is detection and correction of unheeded, unacknowledged deficiencies in diet and health, not the overloading of the system with calcium given in medicinal form (488:165).

An individual stature curve covering the age period from two postnatal months to one year and considered to show the effects of illnesses was presented by Stearns and others (475). The curve showed two major deflections, one around 25 weeks of age, the period of a mild chickenpox infection, and the second following 40 weeks of age, the period of "a severe illness, a laryngitis requiring tracheotomy, wherein the child was critically ill for a period of several days and moderately ill for a month or more." Growth was relatively rapid from about 10 to 20 weeks and 30 to 40 weeks, and in spite of the illnesses the child was found to advance from average stature at two months to 5 cm. above average (Kronfeld standards) at one year. Todd (489) reported that between infancy and puberty individual curves for stature and weight show a steady increase in the healthy child. A study of the vital capacity in young adults, both with references to changes in pneumonia and the range of year-to-year fluctuations in health, was made by Arnett (340).

McLester (430) reported a study of the influence of the depression on the weight and stature of school children. The data were "height and weight records made in 1927 and in 1934 of approximately 20,000 pupils of the Birmingham public schools, representing essentially 25 percent of the total enrolment for the two years. This is an industrial city, the population of which has profoundly felt the effects of the depression . . ." White children were 90 grams heavier in 1934 than in 1927 and Negro children were 90 grams lighter. These findings were considered to "warrant the assumption that during the depression the children in an important industrial area in a large American city have not suffered in the state of their nutrition" (430: 1866). The growth in stature and weight of children one month to five years of age reared with relatively optimum pediatric and home care was studied by Peatman and Higgons (450). The subjects were 577 males and 533 females living in a suburban area of New York and all subject to private pediatric care. The great majority were of northwest European stock and approximately 60 percent from homes where the family income exceeded $3,000. The general principles behind the type of feeding used were: ample caloric intake at all times; relatively high protein intake, intake of solid food, and vitamin intake; relatively low total fluid intake, carbohydrate,

and fat. Sunbaths were given from April to October, and ultra-violet radiation during the winter months. The environment was studied "to insure ample rest and to prevent excessive or harmful stimulation." When compared with means from Woodbury, it was found that "in both height and weight the subjects of the present study start at about the same average point (slightly below). However, after the third month our subjects slowly but steadily increased in average height and weight above the averages of Woodbury's subjects . . ." (450:1246). Statistically significant differences were obtained beginning with the fourth month of age for weight and the fifth month for stature. Waters and Dozier (497) presented findings for Chinese girls subjected to a twenty-week period of exceptional health care. The conclusion was drawn that optimum nurture produced marked results. Since, however, neither the status of the subjects at the beginning of the experiment nor the method of their selection were discussed, the authors' conclusion lacks any quantitative foundation.

Hardy and Hoefer (401) reported the results of a twelve-year research program, one aim of which was to determine "the extent to which participation in a broad health education program during childhood tends to influence rate of growth" in physical size. The general procedure in this connection was to measure a group of Joliet, Illinois, school children at the beginning of the third grade and remeasure them one and two years later. Part of the children received health instruction and part served as control cases. Eighteen anthropometric measurements were taken on each child. Various approaches were employed in analysis of the data. Probably the most rigorous approach was that of equating groups for age, socio-economic status, and mean size at initial examination. For a health instructed group of 85 males and a control group of 34, the means after two years were higher for the former than for the latter by one-tenth inch for stature, one pound for weight, and three-tenths inch for shoulder width. For equated groups of girls, 75 health instructed and 29 control, the findings were in the same direction and similar in amount.

Dentition

Studies on the age of eruption and shedding of the teeth were made by Gesell and Thompson (389), Hardy and Hoefer (401), Hellman (402), Klein and others (419, 420, 421), and Poole and others (452). The latter accumulated data on the appearance of the first deciduous tooth for 102 full-term, single-birth, healthy infants observed during 1934-1935. The infants were drawn from "a cross section of the indigent and near-indigent class of the cosmopolitan populations of Detroit. Approximately two-thirds of the infants selected were white, and approximately one-third, Negro." On distribution of the data, it was found that the range in age of appearance was from 101 days to 340 days and the mean 223 days (7.5 postnatal months). Data on eruption of deciduous teeth during the first postnatal year

were analyzed by Gesell and Thompson (389). The subjects were 107 healthy, normal, full-term, single-birth infants whose parents and grandparents were of north European extraction and of middle socio-economic status. The range in number of teeth was zero to two for both sexes at twenty weeks, zero to five (males) or six (females) at thirty-two weeks, and zero to ten (females) or twelve (males) at fifty-two weeks. Klein and others (419, 420, 421) published data on the shedding of the deciduous teeth and on the eruption of the permanent teeth for 4,416 white children between the ages of six and sixteen years.

On the loss of the deciduous teeth, material presented by Klein, Palmer, and Knutson (420) indicated females to be advanced on males throughout. The mean number of deciduous teeth present in the mouth decreased from 16.9 for males and 16.0 for females at six and one-half years of age, through 11.4 for males and 10.6 for females at eight and one-half years, and 6.0 for males and 4.3 for females at ten and one-half years, to 1.3 for males and 0.8 for females at twelve and one-half years. On the number of permanent teeth erupted into the mouth at successive ages, material presented by Klein and Palmer (421) showed (a) the median number at six and one-half, eight and one-half, ten and one-half, and thirteen and one-half years was 5, 12, 18, and 28 for females and 4, 11, 16, and slightly less than 28 for males. On the age at which specific permanent teeth erupt into the mouth, Klein, Palmer, and Kramer (419) found: (a) for the lower jaw of females means were 6.1 years first molar, 6.2 years central incisor, 7.3 years lateral incisor, 9.5 years canine, 10.2 years first premolar, 11.0 years second premolar, and 11.9 years second molar; (b) for the upper jaw of males means were 6.6 years first molar, 7.5 years central incisor, 8.6 years lateral incisor, 10.4 years first premolar, 11.2 years second premolar, 11.8 years canine, and 12.7 years second molar; and (c) all children examined at nine years and older had four first permanent molars erupted, all children at ten years and older four central incisors, and all children age fifteen years four first premolars. Hardy and Hoefer (401) reported a study on eruption of the second permanent molars. The subjects were 89 males and 88 females between eleven and twelve years of age and 63 children of each sex between twelve and thirteen years. Hellman (402) studied the third molar tooth with reference to congenital absence, impaction, and age of eruption. The data on congenital absence and impaction were accumulated from X-ray examination of 433 Columbia University students—261 males and 172 females, all white and American-born. Approximately 22 percent of the males and 31 percent of the females had one or more congenitally missing third molars. Corresponding percents for impacted molars were 10 and 24, respectively. The right third molars "erupt at the approximate average age of 20.5 years in both the males and females studied, the upper erupting slightly ahead of the lower."

A study of mean size and range of variation for length and breadth of the first and second mandibular molars was reported by Hrdlicka (409).

Broadbent (356) presented a number of serial profile roentgenograms and diagrams illustrating particularly the patterns of movement of the teeth prior to eruption. Goldstein and Stanton (391) investigated posteruption movements of the teeth between the ages of two and ten years. Lewis (424) discussed case records in an attempt to clarify the relationship of thumb- and finger-sucking to the eruption and occlusion of the primary teeth. Sved (479) published an extensive treatise reviewing and evaluating the contributions of Brash, Wallace, Hellman, and Jansen, and presenting a synthesis of the known facts about growth of the jaws, movement of the teeth, and the etiology of malocclusion. Studies on the frequency of caries in deciduous and permanent teeth were reported by Klein, Palmer, and Knutson (420) for 4,416 white children six to sixteen years of age; by Preston (453) for 740 Japanese children of San Francisco, age five to fourteen years; and by Dunham and others (380) for 216 Pueblo Indian children age seven to eleven years. Klein and Palmer (421) studied the relation between age of eruption of permanent teeth and caries experience. The studies by Schour (468), on the neonatal line in the enamel and dentin of deciduous teeth, and Lewis (425), on dental arch growth, have been reviewed under previous captions. Greulich and others (397) briefly reviewed selected procedures and research findings on dentition.

Ossification of the Skeleton

Mershon (443) described the growth of the alveolar process of the maxilla and mandible as follows:

> The alveolar process begins to form when the deciduous teeth are in the process of formation and it continues to develop until all the deciduous teeth are fully formed and have erupted. It remains in that condition until the roots of the deciduous teeth begin to be resorbed. Then the alveolar process and the roots of the deciduous teeth are resorbed simultaneously. When the deciduous teeth have been exfoliated, none of the alveolar process which supported them remains. An entirely new alveolar process develops with the permanent teeth. Its proportions are determined by the length of the roots of the teeth of the permanent dentition and its rapidity of growth parallels that of the teeth. In short, there are two distinct alveolar processes, one for the deciduous teeth and one for the permanent teeth (443:1069).

Certain aspects of this two-cycle course of ossification and resorption were illustrated with subjects at various ages from birth to senility.

A major study on the osseous growth of the hand and wrist was published by Flory (383). Four sectors of the study treated (a) the literature on the problem; (b) a quantitative analysis of carpal growth; (c) a qualitative analysis of carpal, metacarpal, phalangeal growth; and (d) comparison of the quantitative and qualitative methods employed. The age range studied was from birth to twenty postnatal years. A total "body of data comprising more than 6,500 roentgenograms of the hand" were drawn upon. Subjects below five years of age were secured through Chicago hospitals and nurseries, subjects six to seventeen years from the University of

Chicago Laboratory Schools, and subjects eighteen to twenty from the University of Chicago Junior College. Tables were given for the percent of males and females at successive ages showing appearance of each carpal bone and epiphysis, the mean ossified area, specific for age and sex, of each carpal bone, and the mean Carter ossification ratio for each sex at successive ages. Pictorial standards at each age from birth to seventeen years for females and nineteen years for males were presented and discussed. These standards were constructed to facilitate rating of the osseous growth of the hand and wrist, i. e., to yield "skeletal-months" ratings based upon appearance of carpal centers and epiphyses of the phalanges, metacarpals, ulna (distal), and radius (distal); observable increase in size and change in shape of these bone masses; and union of the epiphyses with their respective diaphyses.

> The appearance of epiphyses, the appearance of bones, the appearance of sesamoids, the development of bones, the development of epiphyses, ossification ratios, skeletal-months ratings, and the completion of osseous development all indicate a sex difference in favor of girls. . . . Ossification ratios in the high-school years are relatively poor predictors of the age at which pupils will reach skeletal maturity. . . . Skeletal-months ratings are better predictors of the completion of ossification than ratios or areas. The evidence presented indicates that the skeletal-months technic is one of the most satisfactory methods for evaluating skeletal development (383:127-30).

Clark (362) constructed a table of normal standards for osseous growth based on the age of appearance of the carpal and tarsal bones and on the age of appearance and union of epiphyses for shoulder, pelvis, knee, ankle, foot, hand, and wrist. The table listed the changes at consecutive one-year intervals between birth and twenty years of age. Bilateral symmetry in ossification of the hand was discussed by Pryor (456). He dealt with symmetry in the number and size of the centers of ossification, in the chronological order of ossification of the bones of the carpus, in extra epiphyses, and as seen in polydactylous hands. It was concluded that in view of the numerous opportunities for asymmetry the degree of bilateral symmetry found appeared remarkable.

Todd and his associates (485) published an *Atlas of Skeletal Maturation*, representing upwards of ten years of intensive roentgenographic analysis in an attempt to obtain precise and valid standards for the assessment of skeletal maturation or bodily constitutional status. Over a quarter of a million roentgenograms were accumulated and examined. They covered six areas of the body. The aspects of these areas which came to be judged as giving the most valid information on maturation were: for the shoulder, the head of the humerus; for the hip, the head of the femur; for the elbow, the center of the capitulum; for the knee, the femoral and tibial epiphyses; for the hand, the metacarpals and phalanges; and for the foot, the calcaneus, talus, and cuboid. Specific determinators of maturity were sought in changes in form of shaft ends and subepiphysial shaft surfaces, changes in contour of bony epiphyses and in carpal and tarsal bones, and fusion of epiphyses and

diaphyses. A study relating in part to "standards for anatomic age" and in part to "individual trends for stature and anatomic age" was reported by Kelly (418). The first part of the study reviewed the various objective methods proposed for use in construction of standards of anatomic age, evaluated those methods which applied within the age limits of six to eighteen years (using roentgenograms of the right hand and wrist for 359 white males), selected a highly reliable and practicable index in males of these ages, and determined norms of anatomic age for males at successive six-month ages from six to eighteen years. The second part was based on seriatim data for anatomic age and stature extending over the age period from around six to seventeen years and accumulated on sixty-one males of north European stock. "Prediction of anatomic age at one chronological age from a known anatomic age at an earlier time is a precarious task. . . . The anatomic age of an individual does not aid in the prediction of his stature. . . . Individual stature curves based on anatomic age are more varied and complex in form than like curves based on chronological age" (418:35). Howard (405) discussed the relationship between osseous growth in the hand and wrist and "general growth stages." He assumed that studies by other investigators on "general bodily growth" had shown a spurt stage between birth and seven years, an inhibition or slowing down stage from eight through eleven years, a spurt stage between twelve and sixteen years, and a maturity and inhibition stage from seventeen through twenty-one years. Findings for "the osseous advent and growth of the bone centers of the hand" were interpreted as synchronizing with this general growth pattern. Since, however, in drawing the parallel there was considerable distortion of types of data, the paper appears fairly evaluated as an attempt to state growth laws or relationships at the expense of scientific rigor.

As a byproduct of an investigation on the relationship between sexual maturation and skeletal growth, Shuttleworth (471) obtained averages for twelve osseous dimensions of the hand and wrist on seriatim roentgenograms for 103 females extending over periods from seven to twelve years. Schultz (469) presented a paper on the proportions, variability, and asymmetries of the long bones of the limbs from measurement of adult skeletons of four racial groups. The numbers of male skeletons were 122 each white and Negro, 73 Eskimo, and 64 Indian. For females, the corresponding numbers were 110, 111, 49, and 54. The studies by Roberts and MacNair (461) and Sontag (474) were reviewed in the section treating factors conditioning growth. The former dealt with the effect of a milk supplement on ossification of the carpal bones and the latter with evidences of disturbed neonatal ossification of the tarsal bones.

Growth of Internal Organs and Soft Tissues

Scammon (467) reported a study of growth in weight of the brain and its major parts during the first year of postnatal life. From a series of nearly

1,300 records, those for non-Caucasian infants and those "indicating any involvement of the brain in disease" were eliminated. The total weight of the brain at birth consisted of roughly 93 percent cerebrum, 6 percent cerebellum, and 1 percent brain stem. The average female encephalon was 11 grams lighter than the male encephalon at birth and forty grams lighter at six months. Between birth and the end of the first postnatal year the weight of the encephalon increased over 140 percent, the percent increases being less than this for cerebrum and brain stem and considerably higher for cerebellum. Empirical interpolation formulas were derived for the weight of the brain and its major parts in each sex and in both sexes combined. Calculated and observed values at each month throughout the first postnatal year were compared. Four papers were published by Hesdorffer and Scammon (403, 404, 464, 465) on growth of cerebral surface, volume, and length, and on growth in length and volume of the basal nuclei. The data for the postnatal period were obtained from ten specimens—two for full-term newborns, four between the ages of two months and two years, and four between twenty-five and fifty years. Cerebral surface was obtained both as total surface (entire surface including portion buried in all cerebral fissures regardless of depth) and free surface (visible surface—surface into sulci to where their sides meet). "The medial surfaces of the cerebri were included in both types of measurement, but with the exclusion in both instances of the connecting masses of tissue such as the corpus callosum, the basal nuclei, the surface of the third ventricle, and the like." Cerebral volume and volume of the basal nuclei were each determined by the displacement method. Total cerebral surface more than doubled its birth value (698 sq. cm.) by two years of age (1,666 sq. cm.), and showed a slight decrease between two years and adulthood (1,538 sq. cm.). The free surface of the cerebri increased from 231 sq. cm. at birth, through 457 sq. cm. at two years, to 535 sq. cm. in adulthood. The ratio from dividing free by total surface stood at approximately 33 at birth and 35 in adulthood, indicating that "in postnatal life the 'free' surface is approximately one-third of the 'total' surface, regardless of the cerebral size." Cerebral length increased from 10.6 cm. at birth, through 15.6 at two years to 17.0 in adulthood; length of basal nuclei from 4.0 cm. at birth to approximately 6.0 cm. in adulthood. Volume of the reconstructed cerebri was between 300 to 400 cc. at birth and 900 to 1,200 cc. in adulthood; volume of basal nuclear masses approximately 11 cc. at birth and 51 cc. in adulthood. The geometric rules of dimensionality for objects of simple and regular form were found to hold to a close approximation for cerebral length, free surface area, and volume. That is, empirical equations showed volume equal to a constant times length raised to the 2.9 power, free surface equal to a constant times length to the 1.8 power, and free surface equal to a constant times volume raised to the .66 (2/3) power.

Josephi (414) made "a statistical study of the relationship between various measurements of the heart and body" in normal children from two

to fourteen years of age. Relatively high coefficients for body surface area and cardiac surface area (.91 for males and .92 for females) were found. This finding suggested that the quotient of body surface area/cardiac surface area "should be of value in determining the normality of the heart." A study on the size of the heart in healthy children ranging in age between birth and six years was reported by Maresh and Washburn (431). The data included cardiac area of the frontal plane silhouette of the heart and total transverse diameter (sum of maximum diameters of right and left sides of the heart) determined on 1,026 roentgenograms taken at three-month intervals on 38 boys and 29 girls. Individual curves for both cardiac surface area and transverse diameter showed marked irregularities. For none of the children was the growth curve smooth. In the study of the individual child over a number of years it cannot be assumed that cardiac area has advantages over transverse diameter in the determination of cardiac size. Individual growth curves for the two measurements "suggest that undue emphasis may have been placed on the advantages of measuring cardiac area." The normal range of 11.5 to 15.5 proposed by Josephi for the ratio of body surface area/cardiac surface area "is too small for the period of life up to the age of six years." Sterrett (477) studied fifty males, between the ages of nineteen and thirty-seven years, in an attempt to predict area of the heart shadow on a postero-anterior roentgenogram from a combination of measurements taken on the external body. Roentgenograms were taken in prone position, during deep inspiration, and with exposure of one second to give heart shadow in diastole. Twenty-five external measurements of the head, trunk, and extremities were taken and, from these, six additional items in the form of indexes were derived. The best formula obtained for predicting heart area involved weight, width of hips, face length, and nose width. Predicted heart area from this four-variable regression equation correlated .70 with measured heart area.

Newcomer and Newcomer (446) claimed that the total transverse diameter of the heart "should be discarded" as a heart measurement. The reasons were that it "varies with the angle of inclination of the heart," "does not pass through the same areas at even approximately the same angles in different types of hearts," and, consequently, lacks morphological meaning. They recommended replacing this measurement by the broad diameter of the heart. The broad diameter was defined as the sum of perpendicular lines "from the junction of the left auricle and left ventricle on the left border of the heart to the oblique diameter" and "from the junction of the right side of the heart and diaphragm, which is the junction of the right auricle and right ventricle, to the oblique or long diameter" (446: 523-24). This measurement was reported to give "a fairly accurate and reliable anatomical measurement of the heart at the junction of the auricles and ventricles. . . ." Karpovich (417), as part of an analysis of "Textbook Fallacies Regarding the Development of the Child's Heart," reworked data previously analyzed by Beneke and found that "there is no

discrepancy between the development of the heart and the cross section of the largest arteries." At each age from birth to twenty years, the "heart volume and the cross section areas of the aorta and the pulmonary artery show a close proportionality" (417: 36-37).

Boyd (353) presented "Norms of the Changes with Age and Variation in the Weights of the Parts of the Thymus and in the Number of Hassall Corpuscles" for the period from the close of intrauterine life to senility. She concluded, "These norms show that only the medulla, with its Hassall corpuscles, begins, like the whole thymus, to involute at about the age of puberty, involution of the lymphoid tissue in the cortex having started at four years of age, while the connective tissue and fat continue to increase until old age" (353:335). Change with age and variability in the weight of the normal thyroid gland was studied by Nolan (447). The material consisted of 381 thyroid glands for males and 76 for females, all normal both grossly and microscopically, removed intact at autopsies during the period 1929 to 1934. Thirty-one specimens for each sex were from individuals ranging in age between birth and twenty years, while the remainder were distributed over the age period twenty to ninety years.

Todd (487), in a paper treating the nasal area, succinctly described recent findings made in his laboratory regarding the growth of the pharyngeal tonsil.

> It is only since the precise standardized roentgenograms of the Bolton Study have demonstrated how accurately the adenoid growth can be revealed and objectively measured that one has been able to follow the natural history of the adenoid mass in childhood, its tendency to develop at about twelve months, its increase in size to three years, its stationary condition until adolescence except in those children in whom shrinkage takes place rapidly from eighteen months onward, and finally its gradual recession in size after adolescence (487:327).

A study of the normal weight of the kidneys between maturity and senility was reported by Wald (494). Scammon and Hesdorffer (466) made a study of the growth of the lens in mass and volume during postnatal life.

Todd (485) reported briefly on growth in skin thickness as observed on carefully processed roentgenograms for various parts of the body. Greulich and others (397) discussed the adolescent child with reference to thickness of skin and change in skin color. Boynton (354) made a study of growth in thickness of skin and subcutaneous tissue for girls between birth and eighteen years of age. Jung and Shafton (416) studied the mammary gland in the normal adolescent male with a view to testing the hypothesis that a degree of mammary hypertrophy is a regular feature of normal pubescence. After drawing the conclusion that "enlargement of mammary tissue is probably an invariable accompaniment of adolescent changes in boys," the authors noted that further analyses were being carried out and that older age groups will have to be examined "to observe the complete regression of the phenomenon" (416: 458). Greulich and others (397) reviewed selected research on postnatal changes in the size and shape of the ovary, uterus, and testes.

Pubescence

Hardy and Hoefer (401) analyzed records for date of onset of the menses obtained through the municipal schools of Joliet, Illinois. Records, exact to the month and year, were secured for 109 cases. First menstruation occurred during the twelfth year for 9.5 percent of the cases, during the thirteenth, fourteenth, and fifteenth years for 80.5 percent, during sixteenth year for 8.4 percent, and during the seventeenth year for remaining 1.6 percent. "The average age of the first appearance of the menstrual flow was 13 years 7 months, the onset for 52 percent of the girls occurring between the ages of 12 years 8 months and 14 years 3 months" (401: 102). Pryor (454) reported a study on (a) the age of onset of catamenia, and (b) the status of pubic and axillary hair growth and of breast development at the time of catamenia. Hrdlicka (408) secured records for the menarche on sixteen full-blood Eskimo girls. They were obtained following 1930 by a trained nurse at Bethel, on the Lower Kuskokwim River, Alaska. The mean age of menarche was 13.3 years. Preston (453) reported on the examination of 394 Japanese girls in San Francisco during the winter of 1931, the girls ranging in age from five to fifteen years. Mills (444) made a synthesis of research findings on "the onset of the menses" in relation to "climatic environment" and claimed that recent figures indicate:

> . . . that nowhere on earth do girls mature so early as they do in the central part of the North America. . . . Among the entering freshman class of 1935 at the University of Cincinnati, there were 62 girls 17 years of age with a mean age of menarche of 12.9 years. . . . South toward the Gulf of Mexico, east toward the Atlantic coast, or northeast into Canada, the menses tend to begin at later ages . . . throughout South America the development of puberty is delayed about one year . . . (444:48).

Dimock (378) examined 1,406 males aged ten to eighteen years in attendance at summer camps and determined the pubescent status of each by the "Crampton criteria." Two hundred and sixty of the cases were rated as "pubescent," that is, as showing pigmented yet nonkinky hair in the pubic region. These 260 ranged in age from ten to sixteen years, with 1 percent falling in the eleventh year, 14 percent in the twelfth year, 76 percent in the thirteenth, fourteenth, and fifteenth years, and 8 percent in the sixteenth year. The average age of "pubescence" was thirteen years one month. One percent of the eleven-year-old boys examined were already postpubescent, and 2 percent of the fifteen-year-olds were still prepubescent. Carey (358) employed the "Crampton criteria" for rating pubic hair growth on 259 boys of Saint Mary's Industrial School, Baltimore, Maryland. The boys ranged in age from approximately eleven to eighteen years. Forty-nine were rated as "pubescent." The mean chronological age of this group was fourteen years and three months, and the sigma 12.1 months. Data leading to the conclusion that "enlargement of the mammary tissue is probably an invariable accompaniment of adolescent changes in boys" were presented by Jung and Shafton (416).

Dimock (378) presented findings on the relation between Crampton pubic hair ratings and measurements of stature and weight for boys of Milwaukee and Kenosha, Wisconsin. Thirteen-year-old prepubescent boys were found to average 4 inches shorter and 20 pounds lighter than the postpubescent boys at this age. The average growth of sixty boys who remained pubescent for the year was 1.8 inches for stature and 7.6 pounds for weight. The average growth of sixty-four cases passing from pubescence to postpubescence was 3.3 inches and 16.6 pounds. "Most rapid physical growth comes during the shift from pubescence to postpuberty." Findings on the relation between Crampton pubic hair ratings and measures of stature, weight, and body build were reported by Carey (358) for seventy-one boys age thirteen years. An original index—the sum of hip girth and chest girth divided by shoulder height—was used to determine body build. Carey ventured the conclusion that "there is a marked tendency for those of extreme Asthenic habitus to be retarded in pubertal development and for those of extreme Pyknic habitus to be accelerated" (358:98).

Richey (458) investigated the relation of precocious, normal, and retarded puberty to stature and weight data for school children of both sexes. Approximately 1,850 non-Jewish, white children of each sex, distributed over the age range from six to eighteen years, were employed. As a rule, girls and boys of the early maturing groups are taller and heavier than those of the intermediate maturing groups, and children of the intermediate maturing groups are taller and heavier than those of the late maturing groups. Oddly, "the tallest as well as the shortest boy for whom measurements are available is a member of the latest maturing group" (458:46). Pryor (454) "studied the height and weight increases at six-month intervals for three years beginning at age 10.5 years on eighty girls. . . ." Her data, obtained at Oakland, California, made possible a comparison of the growth in stature and weight of forty girls having attained the menarche with forty prepubescent girls matched for chronological age. The pubescent girls gained weight 59 percent faster during the sixth months preceding catamenia than they averaged per half year for the previous year. Two monographs treating sexual maturation of girls in relation to growth in external dimensions of the body and skeletal dimensions of roentgenograms for the hand and wrist were published by Shuttleworth (470, 471). Both monographs covered the age period six to nineteen years, and were based on materials accumulated by the Harvard Growth Study. ". . . Each of nineteen physical and skeletal dimensions has its own distinctive and characteristic pattern of growth" (471: 52). ". . . while the patterns generated by the increments of the several menarcheal groups are very much alike, they occur at very different chronological ages" (471: 53). "On the average the first inflection point marking the transition from initial decelerating to accelerating growth occurs 3.35 years before the advent of the menarche while the second inflection point in terms of increments and relative growth rates occurs .93 and 1.16 years before the advent of the menarche" (471: 53). An

investigation on relationships between menarcheal age and measures of stature, weight, bi-iliac diameter, and chest width was reported in companion papers by Barker and Stone (346) and Stone and Barker (478). The data analyzed by Stone and Barker were for California girls of north European ancestry between the ages of ten and one-half and sixteen years. Parallel data on Stanford University women aged seventeen to twenty-one years were analyzed by Barker and Stone (346).

Appraisement of Physical Fitness

Age-height-weight tables (weight norms for age and stature) were constructed by Brown (357), McCall (426), Peatman and Higgons (450), Richey (458), and Steggerda and Densen (476). The basic data employed by Peatman and Higgons were age, stature, and weight values (2,633 sets of males and 2,516 sets of females) for children between birth and five years of age reared with relatively optimum pediatric and home care. Separate tables were presented for males and females. The notation was made that "since height-weight norms represent average or long run expectancy, an estimated weight for a given height at a given age has of course a range of normal variation for the healthy child" (450:1244). From a comparative study of stature and weight on rural and urban children of Utah, Brown concluded there was need for specifically constructed age-height-weight tables "to which children of this section of the country could be expected to measure up" (357:15). Consequently, four tentative tables were presented covering the age period six to fifteen years—one each for rural boys, rural girls, urban boys, and urban girls. The tables for boys were each derived from approximately 7,000 cases and those for girls from roughly 6,000 cases. It was stated that since the children constituted "an entirely unselected group, including the subnormal in physical development, along with the others, as well as all races found in the public schools of the state," the tables were given "as an indication of what may be expected as averages in size for the general run of children in Utah communities, and not as standards" (357:15, 19). Age-height-weight tables "specific for the Navajo Indians in the schools of the Southwest and for Dutch white children of Holland, Michigan," were constructed by Steggerda and Densen (476:115). They stated: "When individuals are compared with some given standard it is assumed that the same forces which operated to produce the standard operate upon the individual. . . . Hence, it was deemed preferable, when homogeneous groups were available, to prepare height and weight tables specifically for each group" (476:115). A total of 3,332 Navajo Indian children between the ages of six and eighteen and 3,730 Dutch white children between six and fifteen years served as subjects. The procedure, specific for sex and racial group, was that of "computing equations of average relationship between height and weight by the usual least-squares method and then substituting specific

weights in the equations to obtain average weights for these heights" (476:117). "Auxiliary tables are presented showing the average deviation from the weights in the height and weight tables" (476:120). From evidence that "the body builds of the various maturity groups are somewhat different," Richey (458) inferred ". . . no statement concerning overweight or underweight should be made without consideration of the maturity factor" (458: 61, 67). He then proceeded to prepare tables of "appropriate averages of weight for given age, sex, maturity, and height groups of a private school population" (458:61). Three maturity groups for each sex were used—the criterion was growth of axillary hair in the case of boys and age of menarche in girls. The age range of the tables was six to eighteen years. The caution was given that "the tables should not, in any instance, be used in dealing with individuals without making all allowances for the statistical makeshifts employed, and for the large probable errors of estimate . . ." (458:61). McCall (426) prepared an age-height-weight table for college women of Texas which allowed for variability in weight of a given age group at a given height. The age range was from sixteen to twenty-three years, the height range from 4 ft. 11 in. to 5 ft. 10 in. The table gave the mean weight and the probable error for a given inch of height at a given year of age. It was emphasized that ". . . one figure should not be used in determining the correct weight for a given group of the same age and height" (426:102). (Inspection of the table showed age to improve prediction little over height alone.)

Bayer and Gray (348) published a chart for recording the growth of children of each sex between the ages of one and nineteen years. The chart compared the subject with average values for subjects of like age, and gave a normal zone for each dimension. This "graph seeks to provide a simple visual record in which the growth of a child may be seen as a progressive process related not only to the normal value for that moment but to his own developmental tendency" (348:1409). After discussing their position that "in determining the nutritional status of the individual . . . standards of appropriate weight should not be expressed as a single weight but rather as a range in weight dependent upon body build." Pryor, Shepard, and Moody (455) presented width-weight tables for the age period seventeen to twenty-four years. The tables numbered eight in all—one for each sex at ages seventeen, eighteen, nineteen to twenty, and twenty-one to twenty-four years. Each gave "seven normal weights for each height and age, the variation in norms being based on difference in width of the iliac crests . . ." (455:616). Royster (463) made a study "to determine whether the Lucas and Pryor mean index scale is in fact applicable to the appraisal of the weight of an individual Negro child." The study was based on measurements of stature and bi-iliac diameter for 9,700 Negro children of Virginia age six to fifteen years. It was found that for both sexes and at all ages studied the "Negro child is proportionately of a more slender build than the white child and should not be appraised on the same basis"

(463:262). Allen (338), from a statistical study of "combinations of anthropometric traits," devised a formula for estimating weight of eighteen-year-old college males, based on chest girth and girth of biceps. The multiple correlation coefficient was not given; it was only stated that "predicted weight from this formula has a much higher correlation with actual weight than does height alone" (338:97).

McCloy (427, 429) devised and presented a system of anthropometric appraisal of physical status for use over the entire age period from four postnatal years to early maturity. The presentation was made in two monographs. The first, published in 1936, treated the selection of measurements for appraising physical status. The second, published in 1938, gave norms for each sex at successive ages and explained the application and interpretation of these norms. The variables finally chosen to predict normal weight were: stature, chest girth (corrected for fat), bi-iliac diameter (corrected for fat), and breadth of left knee. Other criteria were listed regarding the selection of measurements to predict normal thickness of skin and subcutaneous tissue, normal muscular mass, and normal respiratory condition. Additional tables presented T-scores for a number of body proportions over various age intervals and norms for various strength tests. The context included detailed instructions in the use of the entire system of appraisal. Marshall (432), using a group of 77 boys aged seven to twelve years, compared four methods of appraising physical fitness: the Baldwin-Wood age-height-weight tables; the Pryor and Stolz age-height-hip-weight standards; the Franzen and Palmer ACH Index; and the McCloy age-height-hip-chest-knee-weight tables. The frequencies of "underweight" for the four methods were found to present marked disagreement. Specifically, they varied from 72 percent of the cases for Pryor and Stolz, through 23 percent for Baldwin-Wood and McCloy, to 5 percent for Franzen and Palmer. A study "conducted for the purpose of determining which of the three indexes of nutrition—Baldwin-Wood weight-height-age tables, Pelidisi or A-C-H—correlated most closely with an experienced doctor's estimate of nutritional status" was reported by Allman (339). The subjects were 1,016 school children, eight to twelve years of age, in the school of Ypsilanti, Michigan, and vicinity. The physician was an expert pediatrician with experience. In the case of girls the Baldwin-Wood tables selected roughly the same percent as malnourished as the doctor's rating. The percent agreement with doctor's rating for boys was closest for the Pelidisi. ". . . the A-C-H index falls down dismally in the number of cases of malnutrition which it detects—in fact, it did not select a single case among the 102 girls in the nine-year age group, while the doctor selected twenty-two or 21.6 percent of this group as showing clinical evidence of malnutrition" (339:85). Of 466 rated as malnourished by one or more scales, only seven were rated as malnourished by all of the four scales. The A-C-H scale is in a large measure responsible for such a great disagreement since the other three scales agree on 75 cases (339:87).

Daniels, Hutton, and Neil (370) investigated the relation of the creatinine-height coefficient to three other indexes of nutritional status. Approximately 500 children between the ages of thirty-six and seventy-two months were used. The nutritional status of the child was appraised by the creatinine-length ratio and "by the three standards most frequently used, namely, weight-height, body build (McCloy) and Pelidisi" (370:536). No consistent relationship was found. Correlation coefficients ranged from –.27 to .57 for creatinine-height with Pelidisi, –.07 to .78 for weight-height, and –.07 to .59 with body build. Equally low and irregular coefficients were obtained for the creatinine-weight ratio with these indexes. Interrelations for various methods of appraisal of health were studied by Hardy and Hoefer (401). The subjects were 409 children eight to fourteen years of age of Joliet, Illinois. The Pearson product-moment coefficient of correlation for the Tuxford index of nutrition with the Pelidisi index was .58; coefficients of mean square contingency for physician's rating (six classifications used) with Pelidisi, Tuxford, and Baldwin-Wood were .48, .47, and .45, respectively. The papers by Derryberry (377), on the reliability of the medical judgments of malnutrition, and Jenkins (413), on a distortion in the Pryor-Stolz width-weight tables, have already been reviewed in other connections. Franzen (385) published "a brief discussion of the basic considerations which should control an evaluation of physical status estimates."

Turner and others (491) made a study "to determine whether poor annual gains could be used as an index in calling attention to children with substandard health." The health status of sixty children gaining less than two pounds in a year was compared with that of sixty children gaining from 100 to 125 percent of the average gain recorded in the Baldwin tables. The children, ranging in age from six to fourteen years, were matched for sex and approximate age. Major physical defects (tonsils, teeth, heart, lungs, sight, hearing, and nutrition) "were found to be more than twice as prevalent among the children having poor annual growth as among those with satisfactory growth records" (491:32). Communicable diseases, noncommunicable diseases, and colds were each roughly twice as prevalent during the year for the poor gainers. "Good growth is one indication of health." An "intermittency in growth" method of selecting school children for health attention was proposed by Turner and Nordstrom (490).

Other studies were considered to have indicated that "growth among healthy children is a reasonably continuous process" and that "disease, poor nutrition, and lack of rest interfere with growth." From monthly weight records, coats and sweaters removed, for 3,229 public school children aged five through twelve years of Malden, Massachusetts, those children who failed to show gains in weight for three successive months were called "intermittent." "We are not yet in a position to say that three month intermittency cannot occur in a child with relatively good health. We are in a position to say that the use of such a screen secures attention for many children who need it" (490:504). Palmer, Kawakami, and Reed (448),

from an analysis of over 8,000 annual weight increments for children six to fourteen years of age, obtained findings considered to imply that deviation from mean-weight-gain for a given age was an "unsatisfactory" method of appraising physical fitness. For example, gains of ten-year-old girls vary from five to fourteen pounds per year depending on whether the girls weigh fifty or ninety pounds at that age. One should estimate gains from both age and weight; but weight alone is better than age alone. Todd (485, 486, 489), discussed the approach to the assessment of developmental health being explored at Western Reserve University. Soundness of bodily constitution is characterized by (a) steadiness of progress in skeletal maturation, (b) steadiness of increment in stature and weight, and (c) lack of osseous scorings, and adequate mineral density of bone, muscle, and subcutaneous tissue. Extensive study had been made of physical vigor as related to gains in stature and weight and changes in skeletal contour.

Cureton (368) reviewed the experimental literature on breathing capacity in an attempt to determine whether it was properly regarded as "a strength test, a flexibility test, a circulatory-respiratory test, or only a test of thoracic size." Arnett and DeOrsay (341) studied the normal variability of breathing capacity in college men and women. Banyai (344) applied a formula for estimating breathing capacity from roentgenological chest volume proposed by Hurtado and Fray, to sixty-five normal healthy adults and found the predictions to fall within 15 percent of the observed values for 97 percent of the cases. Crook (367) constructed a scale for measuring the anteroposterior posture of the preschool child. Baruch and others (347) reported a preliminary experiment "undertaken to incorporate a posture program freely into the daily activities of a nursery school, without set forms or times for work." McCloy (428), from X-ray studies of relatively straight and curved spines, concluded that "there is no one standard of curvature to which all individuals should conform"—accurate methods must be developed for "determining what is the correct standard of posture for each type and for each individual." Greulich and others (397) reviewed selected procedures and findings on posture. Washburn (496), in a discussion of desirable norms, stated:

> The building up of so-called "normal standards" must represent something more than the calculation of averages if it is to be of maximum service to us in the diagnosis of disease. It must consist in the delineation of a "health zone"—a zone within which variations may run from one edge to the other without indicating the presence of disease but outside whose borders variations may not extend without pointing definitely to disorder. Into this zone must be built also a picture of the possible extent of variation for any one individual during the changes incident to growth and development, as compared with the maximum extent of the whole zone for all children (496:32).

The Nature of Growth

Wetzel (498) elaborated the theoretical foundations of his "concept that growth may be looked upon and treated as a mode of generalized motion."

He derived "a set of equations by which the heat production of growing organisms is expressed directly in terms of the corresponding rate of growth" (498:7, 55). A mathematical growth equation was developed by von Bertalanffy (493) on the hypothesis that the growth of organisms results "from the balance of the perpetual breaking down and building up of their component materials." As a "starting point for a quantitative analysis" of organic growth it was assumed that "destruction is proportional to the mass of the organism" and "synthesis is proportional to the resorption of nutritive material, and therefore to the magnitude of resorbing surfaces" (493: 184). Equations for linear and weight growth gave an "excellent fit." Analysis of human growth was considered to entail special difficulties due to the existence of growth cycles.

Davenport and Drager (373) analyzed the form of individual growth curves for stature and weight extending over the age period from birth to twenty-four postnatal months. They found the curves neither "S-shaped" nor "simple logistic" in form. "On the contrary, a period of more rapid growth at six to eight months is followed by a temporary slow growth at sixteen to eighteen months, after which growth proceeds at a more rapid pace" (373:644-45). They concluded that the growth of infants is not controlled by any single reaction, for example, Robertson's monomolecular autocatalytic reaction, but, "is a composite resultant of a lot of more or less independently proceeding growth processes." Implications regarding the nature of human growth were drawn by Davenport (374) from the finding of a rising trend for the brachial index during fetal life and reversal to a falling trend during the first postnatal year. Retardation in growth of the radius was probably due to some specific inhibition gene—"a special gene, or other mechanism, which causes the relative slowing down of cell proliferation and collagen formation at the ends of the radius. . . ." Davenport concluded, "Man is not comparable merely to a colony of unicellular organisms, but is rather an individual organism whose special parts are each controlled by laws of growth of their own . . ." (374:283).

Studies using the method of factor analysis were made by Carter and Krause (359), Marshall (433), and McCloy (429). Courtis (365) presented an original definition of a growth cycle which was claimed to imply a law of cycle growth having "a rational explanation in terms of cause and effect." Meredith (438) stated an empirical concept of physical growth as simply bodily changes which occur in a biological organism with advancing age. Applied to the human organism, it is the changes taking place in size, complexity, form, texture, and pigmentation of the body between the beginning of embryonic life and the close of senility.

CHAPTER V

Technics of Research in Physical Growth and Anthropometry[1]

HOWARD V. MEREDITH

CERTAIN ASPECTS OF METHODOLOGY underlying the studies reviewed in Chapter IV are presented in the present chapter. While these technics are reported in connection with physical measurements, many of them are suggestive of procedures that might profitably be experimented with in other fields of research. They are presented both as a basis for further improvement in technics of studying physical characteristics, and as having an interest that is much wider than the confines of this one field.

Instruments

Cates and Goodwin (360) described an anthropometric board especially devised for taking length measurements on the neonate. A portable anthropometric board for taking similar measurements in the erect position on children of school age was constructed by Carey (358, 509). Ashley-Montagu and Trevor (506) described and illustrated a new sliding calipers with arms curved on one side of the shaft or bar and straight on the other side. The straight portions of the arms were devised to permit measurement of internal diameters, such as those of apertures and fossae. Ashley-Montagu (505) also described a new slide compass with arms straight and of the usual type on one side of the bar and, on the other side, straight but enabling the anthropometrist or craniometrician to determine "the inner marginal limits of such structures as apertures, foramina, or fossae."

An instrument designed to facilitate positioning of the head and thereby permit "accurate production and the duplication of radiographs" was reported by Griffin and Hoffman (517). The apparatus consisted of two major parts, a detachable framework for orienting the head and a series of five extension arms for holding it in position. After the head has been oriented in the Frankfort plane and securely positioned by the extension arms, the field is cleared of the mechanism of orientation and the exposure made with two arms contacting the occipital region, two the parietal regions, and one the frontonasion region. Higley (519) described a head positioner designed for the same purpose as the one by Griffin and Hoffman, but apparently allowing a wider range of adjustment and a more rigorous orientation during exposure. An inexpensive aid in maintaining the head on the Frankfort plane was discussed by Davenport (513). Rona (532) described a device found useful for roentgenographing numerous parts of

[1] Bibliography for this chapter begins on page 133.

the head and face in the erect position. Stecher (535) cited a simple combination of stethoscope and bevel as a means of centering the head. A stethoscope was placed in the subject's ears with the tubing resting either upon the front or back of his thorax.

An inexpensive bevel is positioned transversely upon the metallic stethoscope tubing, and the head is adjusted until exact level of the bevel is obtained (535:116).

A historical survey of the instruments used in taking weight was made by M. Goldstein and Stanton (391). Parallel studies of instruments employed in taking stature and sitting height were made by Ciocco (510, 511). Greulich and others (397) and McCloy (429) each described and illustrated a series of the more commonly used anthropometric instruments.

Landmarks

Howells (521) reviewed the various definitions given to the accepted anthropometric landmarks on the skull and the living head and face in an attempt "to bring out in each case the amount of the discrepancy, where any exists, between such definitions."

1. Discrepancies were found between the definitions of Martin and Wilder for porion, tragion, and vertex. In general, it was concluded that "the definitions of the cephalic landmarks leave much to be desired in the way of uniformity and preciseness . . ." (521:492).

2. Landmarks representing "only the end points of certain measurements, which measurements are necessary for their determination, so that the definitions of the points are merely redefinitions of the measurements" (e.g., alare, euryon, opisthocranion, zygion) were recommended to be banished (521:491).

3. It was given as a "general principle" that "practices of long standing command deference compared with new, if possibly more perfect, ones" (521:493). (This principle appears to place historical precedent even above newer definitions which may be shown experimentally to yield data of superior reliability to older ones.)

A study on the location of the nasion on the living subject was reported by Ashley-Montagu (503). Pending study at various age levels, his general finding for adult subjects of a constant relation between the level of the nasion and that of the highest points of the superior palpebral sulci should not be extended as a calculation for infants and young children. Ashley-Montagu (504) also made a preliminary report on the location of porion in the living. The instability of landmarks employed in determining the growth of the dental arches was cited by Lewis (425): ". . . we measure between certain teeth, using special anatomic landmarks. These landmarks may not be fixed points, since the teeth may change their position during growth" (425:277).

Anthropometric Methods

Maxian (530) suggested an improved "method of correlating the soft and hard structures of the face by using a profile radiograph." A piece of darning cotton was made radiopaque by incorporating a metallic paste into and around it, and then applied to the midline of the face from crinion to

thyroid cartilage just before making the exposure. If one wished to obtain the Frankfort plane on the radiograph, another piece of the radiopaque string was placed horizontally from orbitale to tragion. Higley (520) devised a roentgenographic method for securing valid data on growth in the vicinity of the temporo-mandibular articulation. A "generally applicable method" for obtaining measurements on the living in this and other areas where there is rotation from the conventional planes was described by Campbell and Rubenstein (508). By means of two X-ray views taken precisely at right angles to each other, pairs of shadows representing common points were obtained. From these, corrected coordinate values were calculated from formulas or read from a nomogram. Using the corrected values as true landmarks many pelvic, facial, and other distances otherwise relatively inaccessible on the living, can be determined. Broadbent (356) described a method of superimposing lateral X-rays of the head for the study of age-to-age changes in craniofacial configuration and relationships. The method was reported to focus upon "the most fixed point in the head or face" and to have been fruitfully employed in the Bolton study of facial growth over a period of seven years.

A photo-anthropometric method for use in "the study of craniofacial contour growth in infancy" was presented by Halverson (518).

> The profile of the head and face of an infant are photographed from a given distance. Later a grid-screen marked off into square centimeters is photographed on the same film at this distance. The processed film thus includes not only a picture of this portion of the infant's profile, but also the means of its measurement. If the distances from the lens to the grid-screen and to the sagittal plane of the head are the same, the centimeter divisions on the grid-screen may be used as accurate measurements for the contours of the head and face at the sagittal plane.
>
> Infants are photographed during sleep. This arrangement provides ample opportunity for bringing the apparatus in proper position with respect to the infant's head and insures a picture of the face at rest (518:4).

Crook (512) reported a method used in obtaining silhouettes of anteroposterior posture for preschool children.

> An ordinary Eastman 2-A folding camera was employed. The camera was placed on a tripod in a laboratory which had no outside source of light. The subject was placed on a small stool one foot in front of a white screen of linen sheeting. Five feet behind the screen at the level of the subject's hips was placed a 500-watt light mounted in a diffusing reflector (512:97).

Jones (525) stated that in the California adolescent growth study, body photographs from the front, side, and rear were being taken during standardized conditions of lighting and distance with a specially built camera. These seriatim photographs are being employed "in the study of age changes in various features of gross morphological pattern."

A new adaptation for taking finger, palm, and sole prints was devised by the departments of psychology and biology of the University of Toronto and described by MacArthur and Ford (528). The method consisted of moistening the skin surface with hand lotion or face cream, pressing the sur-

face lightly upon kimeograph paper laid on a rubber pad, rolling a generous amount of finely powdered and sifted lampblack repeatedly over the face of the paper, pouring and shaking off the excess powder, fixing the print from the back in a tray of a solution of 30 gms. of resin to one liter of 95 percent alcohol. "The chief merits of this method are that it . . . avoids completely any staining or even a temporary discoloration of the hands, and it brings out details possibly better than does ink with young children whose fine ridges flatten with the least pressure" (528:8). Irwin (410) developed an objective method for determining change with age in the degree of flat-footedness. Essentially, footprints taken with a pedograph machine were employed to derive a footprint index. A straight line was drawn on the footprint through the two most projecting points corresponding to the medial border of the foot. The area between this line and the inked boundary of the medial border was termed the "noncontact" area. The inked area of the footprint with the exception of the toes was designated the "contact" area. "The contact and noncontact areas were measured with a planimeter and the results recorded in square inches. The ratio of the contact to the noncontact area was obtained by dividing the noncontact by the contact area. This ratio . . . was interpreted as a measure of the height of the longitudinal arch, that is, the higher the index the higher the arch" (410). It was noted that for exceptionally high arches the imprint of the sole was divided into two areas and the index became indeterminate. Two roentgenologic sources from which to obtain measurements of the heart for the living subject—the orthodiagraphic and the teleoroentgenographic—were discussed by Greulich and others (397) and by Newcomer and Newcomer (446). It was reported by the latter that "measurements based upon the two methods are not interchangeable; measurements taken in the erect, sitting, or reclining position by either method are not interchangeable" (446:522). Goldstein (394) studied the comparability of head height measurements taken from porion to bregma and from auricular floor to bregma. A technic for taking projected measurements of head and face features from a vertical plane was described by Davenport (513). "Just as craniologists have used planes of reference so must students of growth of parts in the living use planes where possible" (513:5).

Detailed description of 26 anthropometric measurements in use in measuring infants at the Iowa Child Welfare Research Station between 1933 and 1935 and considered "applicable to children from birth to three years of age" was given by Dawson (515). The descriptions were made with unusual care and thoroughness. It is questionable whether the methods used in taking head length and breadth and measurements of the chest should be considered satisfactory. McCloy (429) published precise instructions for taking some twenty measurements considered useful in appraising the physical status of school children. Greulich and others (397) briefly defined upwards of fifty longitudinal, transverse, and sagittal measurements of the body considered applicable in the study of adolescent children. Hrdlicka (523) re-

ported on the formation of an advisory committee on anthropometric interests at the 1935 annual meeting of the American Association of Physical Anthropologists.

> The object of this Committee was to gradually undertake, alone or with the help of volunteer collaborators, a thorough review of everything relating to anthropometry, and on the basis of the gathered facts to make from time to time desirable recommendations to the society; the ultimate aim being to facilitate, on the soundest possible basis, general agreements that would serve for safe guidance to all American workers engaged in anthropometric research (523:287).

Four reviews (510, 511, 516, 536) have already appeared as a result of the activity of the Committee in drawing up a list of items for special preliminary survey. Stewart (536) reviewed the development of the cephalic index, the component measurements used in its determination, and the classifications that have been proposed. He concluded that (a) maximum diameters should be used in determination of the index, (b) it "would be preferable to name the percental relationship between the maximum length and breadth of the head, the cephalic index, after Broca . . . and to follow Hrdlicka's custom of applying the term 'cranial index' to the skull," (c) the subdivisions of the cranial index are probably best defined as in Garson's International Agreement, and (d) the best tentative subdivisions of the cephalic index appear to be 65 to 70.4 for hyperdolichocephaly, 70.5 to 75.9 for dolichocephaly, 76 to 81.4 for mesocephaly, 81.5 to 86.9 for brachycephaly, and 87 to 92.4 for hyperbrachycephaly. Ciocco (510, 511) surveyed differences in method of measuring stature and sitting height. With reference to the latter he found marked diversity of opinion regarding the position of the legs and concluded it was "imperative to arrive at a . . . uniform and adequate technique of measuring." Regarding stature he took the position that insufficient attention has been given to the advantages derived from measuring the subject while in the horizontal position. In support of this he wrote: "Studies on somatologic constitution require that the patients, ill at times, be in the most comfortable position. Measurements on the living and dead are more comparable when they are taken with the subjects in the same position, as also are the measurements between infants, children and adults" (510:142). Goldstein (516) reviewed historical and current differences in the method of determining weight. He recommended that weight be taken before the midday meal, at weekly intervals during the first year, and semiannually, spring and autumn, thereafter. He further concluded that weight records should carry data on ethnic stock, occupation, economic status, order of birth, limb-stem proportions, stature, and health notes for intervals between weighings. Weight nude was considered preferable to weight in undergarments but not always practicable. The procedure of weighing in a standard garment when nude determinations are impracticable was not discussed. It was advised that when publishing weight studies investigators make specific reference to the methodology used. Boyd (352) gave an excellent critical review of the methods used in measuring and esti-

mating surface area of the body. By direct reference to studies for surface area she described and evaluated the coating, surface integration, and triangulation methods of measurement and the linear or geometric methods of estimation. In general, the methods of measurement were found to be superior to estimation by linear methods, and the method of measurement by integration "to give values 4 percent lower than coating or triangulation." It was emphasized that "the personal differences in manner of applying any one method (of measurement) may overshadow the methodologic differences" (352:132). Dearborn and others (128) described the anthropometric methods employed by the Harvard Growth Study and published a transcript of seriatim data accumulated on approximately 1,550 public school children. Measurements were made with the subjects wearing indoor clothing. Washburn (496) and Waldo (537) each discussed the comprehensiveness of the longitudinal study made by the Child Research Council of Denver on 100 children beginning at birth. The broad scope of the California study of the growth of some 200 children from approximately ten years of age through adolescence was discussed by Jones (525). Krakower (526) enumerated some of the developments relating to anthropometry between 1870 and 1932.

Reliabilities

Sources of unreliability in measuring the human body were discussed by Davenport (514). Consideration was given to inaccurate calibration of instruments, faulty orientation of subject, lack of precision in locating landmarks, and variation in the application of the instrument and amount of pressure used; misreading of the instrument scale, error in recording the reading, and variation in the time and conditions under which measurements are taken, were also considered in the discussion. Cates and Goodwin (360) reported reliability findings for 31 external dimensions determined on twelve-day-old infants. It was not stated whether the observations were strictly independent, i. e., whether in measuring stature, for example, the neonate was removed from the measuring board after each observation and oriented anew for the succeeding observation. Studies on infants employing indirect methods of estimating anthropometric reliabilities were reported by Bayley (349) and Davenport (371). Davenport (a) measured 21 dimensions on 34 infants at frequent intervals during the first postnatal year, (b) plotted and smoothed the seriatim values for each dimension on each subject, and (c) obtained estimates of reliability by regarding the differences between observed values and values for smoothing as measurement errors. The original observations appear not to have been strictly independent since at the successive examinations of a child any marked deviation in a measurement from that previously recorded was checked. Bayley (a) measured head length and width on 61 children at monthly intervals during the first postnatal year and at semiannual intervals between eighteen and thirty-six months, and (b) estimated reliability by calculating coefficients of correla-

tion between the observations for each dimension at adjacent age levels. The average of these correlations was .93 for head width and .88 for head length. Companion studies to check on the reliability and objectivity of fifteen anthropometric measurements taken on eight- and nine-year-old boys were made by Meredith (531) and Marshall (529). The procedure at each examination was: (a) subject removed all clothing, (b) Meredith entered examination room, made observations for each of the 15 dimensions, and left room, (c) Marshall entered, made a like series of observations, and left room, (d) Meredith reentered, and made a third series of observations. By the use of a third person to record the measurements, neither anthropometrist had access to values previously obtained. Painstaking and strictly independent examinations following this procedure were made for 163 cases. Differences between observations by the same anthropometrist were regarded as reliability data and differences between the initial observations by Meredith and those by Marshall as objectivity data. A distribution of each series of differences, accompanied by its median and 90th percentile, was reported. Findings from these reliability and objectivity tables were supplemented by findings from use of the conventional coefficient of correlation and the ratio of each median difference to the mean size of the dimension it represented. Finally, the 90th percentile of each distribution of differences was referred to the mean annual increment for the dimension and quantitative estimates obtained of the time frequency at which consecutive measurements for each of the 15 dimensions studies are profitably made. Here it was found that "while some dimensions are taken to advantage at bimonthly or quarterly intervals, others appear to make no significant contribution to individual growth trends at intervals of less than one year" (531:270). The results of these two studies were considered to have "unequivocal implications for the planning and execution of seriatim growth studies. Certainly the procedure of taking a constant battery of measurements at every examination is indicated to be untenable."

Carey (358, 509) studied the reliability of six body dimensions from duplicate measurement of thirty boys between the ages of about twelve and sixteen years on two successive days. Reliability findings for dimensions, ratios, and ratings determined on roentgenograms of the hand and wrist were reported by Flory (383), Kelly (418), Shuttleworth (471), Todd (485), and West (539). Flory (383) published reliability coefficients for Carter's ossification ratio. "This ratio is found by dividing the area of a quadrilateral into the total ossified area of the carpal bones present in any given hand." A graduate student and an experienced worker each determined the ratio on duplicate roentgenograms for fifteen children of school age. Paired ratios for the expert correlated .98, for the graduate student .97, and for the expert against the student, .98. Kelly (418) determined reliability coefficients for an index of osseous age which she devised. The index was calculated from roentgenograms for 35 boys age eight years and 35 boys age fifteen years and recalculated after an interval of six months

on the same two series of roentgenograms. "The Pearson product moment correlations between the two sets of independent measurements were .99±.002 for the eight-year-old group and .98±.004 for the fifteen-year-old group" (418:20). Shuttleworth (471) obtained reliability coefficients for each of twelve osseous dimensions determined on roentgenograms for 103 girls between the ages of approximately sixteen and eighteen years. The measurements were made on paired X-rays for each girl and were taken one year apart. The coefficients ranged from .99 for length of first and fifth metacarpals to .88 and .86 for maximum diameter of lunate and greater multangular. West (539) determined reliabilities for the sum of the same ten dimensions as were studied by Shuttleworth. The ossification sums were obtained by remeasuring 52 cases at each of three ages, approximately eight, twelve, and sixteen years. At each age reliability coefficients of .99 were reported. Todd (485) made a study of reliability for ratings of maturity assessment on grade school children. Eight students were trained in his principles of skeletal assessment and given roentgenograms of six areas—shoulder, hip, elbow, knee, hand, and foot—to assess. It was found: (a) "Assessors of greatly unequal experience readily assess the maturity of skeletal roentgenograms within a six-month divergence." (b) "Assessment of the hand shows the smallest standard deviation and is therefore the skeletal area which gives the most generally satisfactory results." (c) "Higher maturity stages, such as those representing 10 to 13 years, are less difficult to assess than the lower ranges such as the maturity stages corresponding to 7 to 10 years" (485:19).

Derryberry (377) made a further analysis of data on reliability of medical judgments of malnutrition accumulated by the American Child Health Association and reported in terms of correlations in 1929. One experiment was made using 108 eleven-year-old boys and another employing a similar group of 113 girls. In each case the Dunfermline scale of excellent, good, fair, and poor was used. The boys were each independently rated by six experienced pediatricians and the girls by five women physicians. "In all there were 25 of the 108 boys rated 'poor' by at least one of the physicians, but only one who was so rated by the entire group of doctors. Only three of the 25 were rated 'poor' by as many as four of the six physicians. Two of the cases were given every rating in the scale . . ." (377:265). Of the 113 girls "there were 65 (over one-half) who were rated 'poor' by at least one of the physicians. There were only six of these 65 children, however, on whom all physicians agreed that the nutritional condition was poor. Again, it was found that two of the cases marked 'poor' by one physician were rated 'fair' by another, 'good' by another, and 'excellent' by a fourth physician" (377:266).

Analysis of Data

Gesell and Thompson (389) employed the lunar month interval in analyzing data on physical growth for the first postnatal year and cited advan-

tages for this interval during infancy both from the standpoint of collection and analysis of data. Lunar month periods are equal; they can be readily subdivided into the four-week units upon which our economic life and the household routines of everyday living are based. Klein, Palmer, and Kramer (419) examined the methods of analyzing data on tooth eruption previously employed, and described a method "by means of which the age distribution of tooth eruption may be accurately described by the normal probability function." In analyzing eruption data for the permanent teeth from children six to fifteen years of age, the authors obtained "for each type of tooth the distribution of the percent of children in yearly age groups in whom the tooth had erupted" (419:386). These distributions gave characteristic S-shaped ogives when plotted on arithmetic paper and "fairly regular straight lines" when plotted on arithmetic probability paper. Consequently, it was stated: "The absence of marked variation of the observed percentages from the linear trends on probability paper makes readily possible the drawing of 'free-hand' straight lines through the plotted data. From these lines for each type of tooth, the means and standard deviations of the normal curves may be read directly with considerable accuracy" (419:387-88). Other advantages of the normal probability function in the analysis of tooth eruption data were also discussed.

Several uses of the standard deviation in the analysis of anthropometric data were discussed in a paper by Howells (522). Two aspects of the paper, one reporting an empirical finding on the number of observations necessary to yield stable sigmas and the other proposing a sigma ratio for making comparisons of group variability, will be reviewed:

1. From an analysis of sigmas for stature and nine dimensions of the head and face on over 150 samples of adult males of different racial stocks it was found that "a series of 50 was the smallest of which the sigmas could be accepted as affording any information as to group variability. Series numbering from 10 to 25 cases gave extremely erratic sigmas, but as the number increased beyond 50 there was no appreciable diminution in variability, and only a very slight increase in the average size of sigma" (522:598).

2. It was suggested that for any given character, the mean of a series of sigmas from various groups of 50 or more cases on like age and sex be calculated and applied as a standard to individual sigmas. That is, "To facilitate comparisons of group variability, etc., the use is suggested of a 'sigma ratio' between any given standard deviation and the mean sigma for the character . . ." (522:600). Some of the claims made for this ratio were: "In dividing the standard deviation by the mean sigma all characters are reduced to a common denominator as to the unit of measurement involved, as to relative dimensionality, and as to the variability of each character per se, while in dividing the standard deviation by the simple mean, the last factor is ignored. . . . A final advantage is that the sigma ratio has also an abstract point of reference, i.e., 100, so that a mean sigma ratio greater than 100 implies a group characterized by greater than average variability, and the reverse" (522:595).

Seltzer (533) presented evidence indicating that the coefficient of racial likeness "is in many respects defective in its construction, in theory, and in actual practice. . . ." Among the constructional defects analyzed were:

(a) the failure of the coefficient to take into account the correlations between the characters dealt with—it rests on the assumption that characters dealt with are independent, (b) its decrease with an increase of the number of characters used in the computation, and vice versa, and (c) its rise with increasing size of sample—this follows since the denominator of the coefficient formula becomes smaller with larger samples. The contention that the coefficient gives dubious results in practice was supported by such findings as that "two groups of English crania are no closer racially than a group of English and Chinese skulls" (533:107). Wallis (538) elaborated on his earlier investigations of "anatomic lag" in a study based on an unusually extensive series of paired anthropometric dimensions. Anatomic lag was defined as "the tendency of an anthropometric dimension to lag, in relative value, upon another with which it is correlated" (538:87). It was claimed that "much anthropometric work is concerned with proportions, that is, with relative values of two dimensions. If index is a function of dimension, that is, if there is lag or acceleration of one dimension upon another, then dimension must be held constant when comparing proportions between two groups if we wish to know to what extent the difference in proportion is a group phenomenon as distinct from a mere biometric phenomenon" (538:87). "During growth head length lags less on head breadth than conversely for ages 6, 7, 9, 13 in males, and 6-10, 13 in females; the converse holds for ages 8, 10-12, 17 in males, and 11, 12, 14-16 in females. In all large adult series head length lags more on head breadth than conversely" (538:118).

Jenss and Bayley (524) presented a mathematical function for "describing quantitatively the growth of a child during the first six years of life," illustrated its application, and discussed several of its possible uses in analysis of growth data. They stated that the growth of length and weight, observed at irregular intervals during the first six years of life, is described satisfactorily in terms of the first derivative of the equation, expressed as a percent of its integral value. "The application of this technique . . . has one specific advantage over other methods . . . namely, the determination of . . . the acceleration factor . . ." (524:561). A mathematical analysis of the consequences of sigmoid growth curves for relative growth functions was made by Lumer (527). Following the claim that "growth curves which extend over a relatively large portion of the growth period are most frequently sigmoid in character, rather than exponential or parabolic," a mathematical discussion was given on the relative growth functions derived from each of three sigmoid equations commonly employed in the analysis of growth, i.e., the simple autocatalytic, the generalized autocatalytic, and the Gompertz (527:141). Courtis (365) reviewed the existing definitions of a "growth cycle" and proposed a definition which he considered more adequate. A cycle of growth was defined as "a period of specific maturation during which all the elements and forces acting are constant within allowable errors of control and measurement."

All trends resulting from growth under the conditions of this definition were considered to have a common form and to be adequately described by the Gompertz equation.

Jenkins (413) cited a distortion in the Pryor-Stolz width-weight tables due to a statistical error in their construction: In the construction of the Pryor-Stolz tables, the center hip width for each age and sex was obtained as the mean of the measurements of bi-iliac diameter for that age and sex. For a given age and sex this value is no doubt larger than bi-iliac means for the shorter heights, and smaller than the bi-iliac means for the taller heights. The assumption that children at each inch of height, specific for age and sex, have the same mean bi-iliac diameter was considered, in practice, to have resulted in tables which predict "weights too low for children short for their age and weights too high for children who are tall for their age" (413:128).

Brody (507) emphasized the fact that a given chronological time unit has a different growth meaning in the life cycle of different organisms, at different ages in the same organism, and for different segments, organs, and tissues of the body.

Shuttleworth (534) compiled an atlas which may be regarded as an exhibit of graphic and pictorial methods useful in the analysis of physical growth data, covering adolescence especially.

CHAPTER VI

Relationships in Physical and Mental Development[1]

HAROLD E. JONES

TWO EARLIER REPORTS, in the April 1933 and February 1936 numbers of this *Review* (570, 571), presented results from approximately 250 studies dealing with the interrelation of mental abilities and specific physical characteristics. It is now well established that a low positive correlation, rarely higher than .30, exists between the intelligence of children and their physical development as represented, for example, in measures of height or weight. Within recent years increasing attention has been given to the formulation of hypotheses concerning the nature of this relationship. Following are several of the alternatives which may be considered:

1. A common biological factor or group of factors may favor superior development of the total organism; absence of these factors may have a generally handicapping effect.
2. Disease effects or the effects of birth injury, malnutrition, etc., may be expressed both in the brain and in other organs with parallel disturbances in later development.
3. Any condition producing an arrest or distortion in the growth of intelligence or of the central integrative functions may thereby indirectly handicap the normal development of other functions and other structures.
4. Social advantages or handicaps may simultaneously influence physical development (through nutrition and regimen) and mental development (through education).
5. Physical-mental relationship may not be due primarily to a correlation of superior or inferior status, but to a correlation of rates of growth; in this latter case, relationships would be expected to diminish in degree at the end of the growth period.

The above hypotheses are not mutually exclusive; their relative importance remains to be determined in further investigation.

Evidence from Correlational Studies

Wilson and Flemming (314) studied interrelationships of physical and mental traits among 25 first-grade children from a restricted superior socio-economic selection. No correlations significantly different from zero were found between mental age and nutrition, height, weight, strength of grip, motor coordination, and steadiness. While results of greater significance would be expected from a more representative sample, it is doubtful that much further attention should be given to correlational studies dealing with cross-sectional analyses of limited samples. A more useful type of investigation is now available, presenting a series of correlations at successive ages for the same or for comparable samples.

In an important study Abernethy (540) has reported correlations be-

[1] Bibliography for this chapter begins on page 134.

tween physical and mental growth among 179 boys and 178 girls in the Laboratory Schools of the University of Chicago. Since tests and measurements were obtained at birthdays, coefficients could be computed at successive ages without recourse to the less desirable method of partialling out chronological age. Correlations between intelligence scores and height were positive at all ages from eight to seventeen, the highest being .34 ± .06 for boys at age eleven; the average *r* was .26 for boys and .16 for girls. Coefficients were also positive, but they were slightly lower and frequently not statistically significant for intelligence as related to sitting height, weight, ossification ratio, chest girth, and lung capacity. In general, *r*'s appear to be lower for girls than for boys, and lower in late than in early adolescence. With several groups of college students, *r*'s were close to zero. Abernethy concluded that the trend of decreasing correlations between mental and physical measures in late adolescence is in harmony with the hypothesis that the relationship is essentially a growth relation. However, when correlations were computed between increments in mental scores and increments in physical measures, these proved to be close to zero, averaging from —.02 to .06 for intervals of a single year. That is to say, over short periods individuals who show a given degree of physical growth do not tend to show an associated degree of mental development. Thus, if growth rates in different functions are correlated the degree of relationship must be too small to be manifest within a year's period, or, as an alternative possibility, the relationship if present may involve a time lag rather than concurrence in time, and would hence involve a different type of statistical analysis such as that proposed by Wallis (538).

Abernethy's study, based on a sample aged eight through adolescence, is supplemented by the report of Honzik and Jones (566) on the mental and physical development of 127 boys and 125 girls receiving repeated examinations from twenty-one months of age to seven years. The California Preschool Mental Scale was used to five years of age, and the Stanford-Binet at six and seven years. At age seven, mental scores correlated .19 with height and .16 with weight; no sex differences or definite age trends were noted. Consistently positive but low correlations were also found between increments, suggesting the role of a growth factor having some degree of commonality for the different functions. Because of the possibility of attributing this to environmental advantage, that is, children in superior homes receiving better nutrition and greater intellectual stimulation, socio-economic factors were partialled out without any marked effect upon the correlations. The relationships also remained when natio-racial heterogeneity was reduced by restricting the sample to those of north European descent.

Related Changes in Growth Curves

The longitudinal data which are now available from growth studies at Harvard, Chicago, California, and elsewhere permit the analysis of rela-

tionships through the comparison of actual curves of growth. It is conceivable that such a comparison, based on a parallel series of points rather than on a correlation at one point in time or on the correlation of increments between two points, may reveal simultaneous variations, or systematic variations with constant time lags, which could not be discerned by ordinary mass statistical methods. Abernethy (540) has used this procedure, applied to group averages. To render them comparable, mental scores and physical measures have been converted into percents of the total increment from age eight to seventeen—thus, all scores are recorded as 0 at age eight, 100 at seventeen. In these terms, girls show an approximately linear growth in various physical measures to about the age of fourteen, with a sharp drop (negative acceleration) thereafter. Boys exhibit a slight positive acceleration at age twelve and a negative acceleration at sixteen. Comparable changes cannot be clearly shown in the case of the mental growth curves. A limitation in this material is the fact that samples in successive years are not entirely the same, and that selective factors are probably operative in the later high-school years. For small groups of boys, however, Abernethy was able to examine growth in constant samples remeasured for five consecutive years. The increment for the first year, in a given function, was taken as 100, and increments for each subsequent year were computed with 100 as a base (dividing the initial year's increment into the gain of each following year). The resulting rate-of-growth data, in terms of averages for groups, showed concomitance between some of the physical measures, but justified Abernethy's conclusion that there is no relation observable between minor fluctuations in mental and physical development. It should be noted that the foregoing analysis was based entirely upon group averages, which may have masked significant physical-mental relationships occurring in individuals.

Honzik and Jones (566) presented growth curves for selected individual cases. For curves of intelligence, height, and weight, comparability was obtained by reducing all measures to standard deviation values, in terms of the means and sigmas of the total group at each age from twenty-one months to seven years. A number of cases exhibited a correspondence of mental and physical growth trends which would not be predicted on the basis of chance or on the basis of the low order of correlation ordinarily reported. Concomitant downward as well as upward trends were noted. Parallel trends were also noted in cases in which there was a considerable separation in level. These, then, are cases in which growth constants for physical and mental functions are similar. The similarity is apparently not produced by common environmental factors during the growth period but may even to some extent be obscured by these factors, as indicated by the fact that correlations with socio-economic indexes increase in the case of the mental score but remain constant for the physical measures. The same report, however, shows other cases in which mental and physical growth curves are quite independent or even divergent.

Future work in this field will probably concentrate upon the attempt to understand individual differences in relationships, rather than to arrive at general laws applicable to heterogeneous groups. For such an understanding, we must look to studies making use of comprehensive findings from different disciplines. The increasing utilization of interdisciplinary data in the study of child development is shown in recent reports by Toulouse (588), Hetzer (565), H. E. Jones (525), Dearborn and others (128), Freeman (137), and others.

Body Build

Studies of body build or body types have in general yielded little of interest with regard to physical-mental relationships. Earlier studies which indicated a positive relationship, lower intelligence accompanying a stocky or "pyknic" build, have been criticized as involving a probable age factor or race factor invalidating the results. Franzblau (557) has restricted the effect of ethnic factors by applying mental tests (the International Intelligence Test) and physical measurements to Danish-American and Italian-American children in New York, to Danish children in Copenhagen, and Italian children in Rome. The possible disturbing effects of selective migration are also to some extent controlled by this procedure. When age was held constant, zero relationship was found between intelligence and weight-height ratio, and between intelligence and cephalic index. In a study using somewhat sketchy procedures in data collection and analysis, Bandlow (542) reported that among 428 graduates of German secondary schools, those of "schizophrenic" slender constitution had a higher scholarship record than those of "cyclothymic" stocky build. Schlesinger (584) has reviewed the literature of the past fifteen years on physical constitution in relation to mental abilities; some indication of a relationship was found in about half of the reported studies.

Among four groups of students at the University of Michigan, Pillsbury (579) studied the relationship between scholarship (honor point ratio) and the Pignet index (height in centimeters minus the sum of weight in kilograms and chest circumference). Coefficients ranged from .05 to .29, suggesting an association of scholarship grades with asthenic habitus. An index in the middle range, however, was more favorable than one at either extreme. Pyknics not only made a lower ratio of honor points but also showed a definitely greater tendency to drop out of college. Hetzer (564) has studied the development of ability as measured by the Bühler-Hetzer tests, in relation to changes in body form among Viennese children. Her summary states that "Zeller's investigations have shown that between five and seven the child's body changes to a form qualitatively different from that of a young child. Psychological investigations show that there is a mental change corresponding to the change of bodily form, and that it is possible to establish body-mind developmental types. Children of babyish form have babyish minds and in general are not ripe for school." Similar

clear-cut results have not been obtained in typological investigations in this country.

Smith (586) computed weight-height ratios from data previously published by Gowin; among ecclesiastics, men of high rank were shown to have higher average weight-height ratios, indicating heavier build, than small town preachers; a similar contrast exists between sales managers and salesmen, railroad presidents and station agents, university presidents and presidents of small colleges, etc. Smith believed that this indicated a relation between body build and "ascendency," determined probably by underlying common factors in glandular constitution. No reference was made to age factors; in view of the relationship of body build to age, it is difficult to appraise Smith's findings. Weisman (589) has examined the relationship between chest form and school performance in a large group of Minneapolis children. When "A" students were compared with those who were failing, the former were found to be taller, heavier, and also to have less deep chests. The conclusion was made that "flat-chested children have better school grades." No correlations are given, and the statistical treatment is not adequate.

It will be noted that the majority of the foregoing studies deal with body build in terms of superficial measurements; the relationship of body constitution to mental traits is a problem which in the future should make use of a more basic physiological approach.

Intelligence and Cranial Measurements

For 1,023 boys, Müller (577) correlated teachers' ratings with cranial width, height and circumference, cranial index, and cranial type. Slight relationships were found with the actual measurements, but none with the indexes of head shape or type.

Hamilton (562) has reviewed over 300 publications dealing with intelligence and the human brain; 38 of these are discussed in reference. Cranial measurements, the relative size of parts of the brain, the vascular system of the brain, and the development of the supragranular cortex are among the factors which have been considered. No competent studies have found correlations higher than .15. Hamilton concluded: "If there is a roughly specific localization of function within the several lobes of the brain, it is apparent that special development of a particular area should be paralleled with unusual talent associated with that area. Such principles, however, do not fit experimental findings. Individual differences in intelligence may be determined by one or two anatomical factors which may some day be isolated or they may be determined by such a multiplicity of factors as to preclude any simple solution" (562:320).

Ashby and Stewart (541) have pointed out that in the lower ranges of intelligence all cranial measures tend to decrease with decreasing IQ; the relationship with intelligence, however, is more marked for measures of

body size than for head size. This fact is compatible with the hypothesis that mental subnormality is essentially an arrest or retardation in development.

Post-mortem measurements of various parts of the brain have been reported by a number of investigators; in one such study Berry (543) analyzed a series of measurements of the brains of 31 mental defectives. Especially noted were a tendency to subnormal size of the total brain, and an inferior development of the parietal lobes.

Physical Abilities

Conflicting results have been obtained concerning the relationship of intelligence to athletic abilities. Among 290 college students Di Giovanna (551) reported approximately zero correlation (ranging from —.20 to +.22) between intelligence as measured by the Otis test and athletic ability as determined from track events. Correlation of intelligence with the Brace test was also approximately zero. Among secondary-school boys, however, Seegers and Postpichel (585) and R. H. Jones (572) found a small positive relationship between intelligence and measures of athletic ability or athletic distinction. Hopfenmüller (567) obtained similar results in studies of gymnastic abilities among German high-school children. Abilities depending primarily on strength correlated less with intelligence than gymnastic feats involving speed and precision of response. In a study of French children from eight to fourteen years of age, Abramson and Le Garrec (88) found correlations of .30 for boys and .31 for girls between IQ and a motor quotient based on the Oseretzki tests. The February 1936 issue of this *Review* reported similarly variable findings, with an apparently greater tendency for positive correlations among the more mature and more homogeneous groups in college.

That normal mental development may occur even under conditions involving extreme motor disability has been demonstrated in several reports. The most recent of these, a case study by Gesell (558), reported a child afflicted with cerebral palsy as a result of birth injury; the child showed an extremely marked handicap of motor functions, without corresponding effects upon mental, motor, or social development. No attempt will be made here to review the extensive literature on the relationship between intelligence and measures of reaction time or of fine coordinations. In general, it may be noted that this relationship is no closer than in the case of gross motor functions, except in test situations which place a premium upon "mental" factors of discrimination or precision in movement.

Physical Condition

The present section is concerned with reports on intelligence or scholarship as related to general health or to the frequency of illnesses. The literature on mental changes attributable to specific pathology—cerebral tumors,

traumata, epidemic encephalitis, epilepsy, and psychoses of childhood will not be reviewed here.

Giaque (559) correlated school grades and IQ with a physical fitness index. The highest value was —.25 with IQ. Giaque interpreted this as due to the influence of schools in inducing the more intelligent adolescents to concentrate more on mental than on physical activities, with a resulting decline in physical fitness. His explanation seems somewhat uncalled for, in view of the fact that the correlation is not significantly different from zero.

Street (587) compared mentally superior children with average children in a Michigan elementary school; no differences were found in physical fitness. Stout (284) in a study of ten-year-old children selected as close to average in intelligence, found a wide range of physical defects, suggesting that "the fact that a child is normal in intelligence gives little or no clue as to what his health or physical condition may be." In a study of physical defects in relation to school failures, Lewis (575) found among grade repeaters in North Carolina schools a relatively heavy incidence of uncorrected visual defects, defective tonsils, and defective teeth; defective nutrition was a less prominent classification.

Adding to earlier studies on the intelligence of children prematurely born, Brander (545) investigated the mental status of premature children, weighing less than 2,500 grams at birth, who were tested after reaching school age, with a Finnish translation of the Stanford-Binet. The handicapping effect of prematurity was suggested by a positive correlation between birth weight and later IQ, and by the fact that no cases of normal mentality were found among children whose birth weight was less than 1,500 grams. Eleven percent of the total sample of 376 cases had IQ's below 70. It has previously been pointed out that prematurity itself involves no necessary disturbance to subsequent mental or physical development, but that prematures are more liable to birth injury than children born at term (583). Melcher (59) has briefly summarized recent European literature in this field, with an added contribution based on a study of 42 premature children; these were tested with the Bühler-Hetzer infant tests at various ages from birth to eighteen months. A low positive correlation was found between birth weight and DQ (developmental quotient); moreover, children whose birth weight was less than 2,000 grams showed considerably lower DQ's than did children closer to normal birth weight. If it were possible to correct these DQ's for the amount of prematurity, with conception rather than birth as the reference point, the differences would be reduced but apparently not wholly eliminated.

An extensive bibliography on tonsils and adenoids as related to intelligence has been prepared by Brander (546), together with a further study of 373 prematurely born children, chiefly in the ages of seven to fifteen years. A positive relationship was shown between mental retardation and tonsilar hyperplasia. Three hypotheses were advanced to account for this: (a) tonsilar infections may directly impair mental development or produce

an indirect interference through impaired hearing; (b) tonsilar hyperplasia and mental retardation may have the same cause, in early developmental disturbances; and (c) mental retardation involving poorer hygiene may increase the tendency to tonsilar infection. In contrast with these findings, England (553), in a study of 959 rural children in Lincolnshire, reported no relation between intelligence and the total incidence of tonsilar disease, although the percent with tonsillectomies was markedly higher among those of superior intelligence in the same study. England found no association between intelligence and any of the infectious diseases of childhood; the total incidence figures were very similar to those reported by Terman for American children of high IQ. Iancu (569) has reported evidence from case studies that children suffering from adenoids show little change in intelligence but are apathetic and deficient in attention—symptoms which he attributed to general underlying factors rather than to specific effects of adenoids.

Hardy (563) and Hardy and Hoefer (401) have reported correlative improvement in health and in school achievement of children who participated in a health instruction program. Their gains, which were greater than in "non-instructed" groups, were not attributed solely to the health content of the teaching project or to improved health regimen but in part to other aspects of the program involving systematic conferences with teachers, principals, and parents.

Indirect evidence concerning the possible effects of poor regimen may be obtained from studying the development of children in contrasting physical environments. Dubnoff (552) has compared mental scores for 489 infants in Kazan, Tatar Republic, U.S.S.R., with scores on the same tests administered to infants from a superior socio-economic selection in California. The California Infant Mental Scale was used. The Kazan sample showed a marked superiority to the California sample at each month from one to nine months. This would not be expected if early mental development were intimately dependent upon good physical conditions; Dubnoff discussed differences in the regimen of the two groups and pointed out unfavorable factors among the Kazan children with regard to diet, exposure to sunlight, opportunities for motor activity, and health. The group differences disappear at about the age of ten months; this may be due in part to changes in the composition of the test in the later ages.

Influence of Month of Birth

Indirect evidence concerning the effect of physical factors upon mental development has been presented by Huntington (568) in an elaborate discussion of the "basic animal rhythm" in ovum fertilization. He pointed out that a basic rhythm involving an increase of conceptions in the spring is characteristic of many species, including man. Children conceived at the height of this rhythm are more equally divided between the sexes,

have a lower infant mortality, and have greater longevity. Several lines of evidence indicate also that persons of the highest eminence are more likely to be conceived at this time and to be born in the winter months. Among individuals listed in the *Dictionary of American Biography*, the relative incidence of births in February and March is related to the degree of distinction. Huntington attributes this to better climatic conditions at the time of conception and during early pregnancy, predisposing greater average physical vigor and more favorable general development. It may be noted that the findings for eminent persons are not supported and indeed are even reversed when we turn to data on IQ of normal populations, tabulated according to month of birth. Huntington has combined data for school children, previously reported by Pintner and Forlano, with new material on over 3,000 children with IQ's of 130 or higher. Children of low and of medium social status, with average IQ's of 93 and 101, respectively, show February as the most frequent month of birth. Those of high social status, averaging 115 IQ, have their greatest incidence of births in March and April, while those with IQ's over 130 show a distinct peak in April. Huntington offered numerous ingenious explanations to account for discrepancies in the data for normal populations as compared with results for eminent persons. It is not clear, however, that he has fully accounted for the complex operation of cultural factors affecting conceptions and abortions. The various seasonal trends in births cannot be denied, but their explanation in terms of meteorological and resulting physical factors must be subject to doubt until more direct evidence is obtainable.

Fialkin and Beckman (554) have investigated the month of birth of 3,189 adult males as related to their scores in the Pressey Senior Classification and Verification Tests, which they state are "accepted as educational achievement tests and as indirect indicators of general intellectual capacity." A difference of less than 3 IQ, too small to be statistically significant, was found between those born in winter and those born in months of moderate temperature (spring or fall). Since, however, the results were in the same direction as those previously reported by Blonsky, Pintner, and Pintner and Forlano, the consistency of findings was regarded as establishing the fact of seasonal differences. This conclusion was based on the use of R. A. Fisher's chi-square method for obtaining a combined probability from discrete measures of statistical significance. Support for this view has been given by Pintner and Maller (580) who analyzed IQ in relation to birth month for each of three ethnic groups—Negroes, Italians, and Jews. In each sample small but statistically significant differences were found in favor of those born in the late spring, summer, or fall; a related difference was found in the health statistics for the warmer as compared with the colder months.

Influence of Month of Observation

Another aspect of the influence of season may be found in connection with seriatim mental test records analyzed with reference to the month or the season of testing. Wellman (590) has reported IQ's for 45 children from two to four years of age tested four times at approximately six-month intervals. They made striking gains in IQ from fall to spring, but negligible gains from spring to fall. All of these children were in nursery school during the fall-to-spring period and Wellman considered that the gains were due to environmental advantages enjoyed in the nursery school rather than to any direct effects of season. The issue, however, has become somewhat complicated as the result of a publication by Lodge (576) of results for 171 preschool children who were not, as a group, members of a nursery school. Gains were shown in any six-month period including the fall months (September to March, or June to December). Losses were shown in any six-month period including the spring months (March to September, or December to June). The factors of age and of test practice were statistically controlled. The seasonal factor was interpreted by Lodge as due either to some differential characteristic of the seasons affecting test performance, or to seasonal fluctuations in rate of growth, with acceleration in the fall and retardation in the spring. He added, "The present findings, instead of contradicting the notion of constancy, actually indicate that the variation ordinarily expected may be somewhat reduced if the seasonal factor is held constant—if children are tested at the same time each year" (576:394).

Birth Rank

The influence of physical factors has also been suggested in an analysis of data on birth rank (568). Previous reviews have indicated that where other factors are adequately controlled, IQ is unrelated to birth rank in normal populations. But in the study of cases of outstanding achievement, certain interesting results may be noted, as in the following table based on 1,210 persons chosen as being above average in achievement in terms of their biographical records in *Who's Who in America:*

Size of family	Birth rank 1	2	3	4	5	Total number of cases
2	59	33				92
3	73	35	32			140
4	53	42	47	28		170
5	43	34	22	24	18	141

The table indicates a relatively high incidence for the first-born and a low incidence for the last-born. For families larger than five or six this relationship breaks down. Huntington reviewed this material together with

similar data previously reported by Cattell and Havelock Ellis, concluding that the advantage of the first-born lies primarily in better health, and is attributable to the effect of the health of the mother, and perhaps of the father, upon the vigor of the child at conception and during pregnancy. Previous reviews have pointed out the treacherous nature of birth-rank data when such material is utilized without controls; even where significant differences appear to be well established, we must regard an explanation in physical terms as little more than conjectural. Huntington's use of vital statistics and of data compiled from biographical sources is valuable chiefly in opening areas of research and in suggesting hypotheses. The next step would seem to require records, not as yet available, presenting for individual cases actual developmental data which are now known only by inference.

Other studies of birth rank, because of their doubtful relevance to the topic of physical-mental relationships, will not be reviewed in this section. It is well known that, as compared with the earlier-born, the later-born tend to have a greater birth weight and a smaller incidence of labor complications. Goldstein (390) has published a recent bibliography in this field, with additional results confirming the above. Similar birth-rank differences in intelligence are not as easily demonstrated. The influence of maternal age, as distinct from birth order, has been studied chiefly in relation to the increased incidence of certain pathological conditions among the children of older mothers. Reviews of this material, with additional data on mongolian idiocy, have been made by Penrose (578) and Bleyer (544).

Evidence from Studies of Mental Defect

Relationships which are low in degree for a representative sample of cases sometimes emerge into sharper relief at the extremes of a distribution. This is not the place for an exhaustive review of the recent literature on the physical characteristics of the feeble-minded; only a few illustrative findings will be reported.

Shuttleworth (534), in a "graphic and pictorial atlas," has presented a series of charts from earlier studies demonstrating in lower IQ groups (a) slower physical growth, (b) slower dental development, (c) greater incidence of physical defects, and (d) shorter life expectation. A competent survey of the literature, with added findings, has been published by Flory (555). He concluded that mentally deficient boys grow slower than normals and remain immature for a longer period; the degree of deviation in physical traits was related to the degree of mental defect. The implication was drawn that a separate set of physical standards should be prepared for mental defectives, and also a separate set of age standards to determine the period of compulsory schooling.

Burt (548) has considered the problem of the backward child in English schools, discussing malnutrition, sensory defects, etc., as factors in

producing dullness. Dayton (550) has analyzed results for over 30,000 retarded children examined by traveling clinics in Massachusetts, concluding that children of subaverage height or weight tend to make a poorer showing mentally than children who are physically normal. With regard to weight, those who are close to average tend to achieve higher intelligence scores than those who deviate either toward underweight or overweight. Goldwasser (561) has compared 900 retarded children in Los Angeles "development schools" with 2,700 normal children in the same neighborhoods. Although receiving more medical care through the schools and more nursing service the retarded children showed a higher than normal incidence in every category of physical defect.

A number of studies have brought out differences between the feeble-minded and normals in various aspects of manual ability (547, 556, 581), motor reaction (560, 573), and motor chronaxy (574). In interpreting such findings Davenport (549) concluded that the feeble-minded as a group are characterized by "general" subnormal development. A similar position was apparently taken by Flory (555). Quinn and others (582), however, attempted to classify the feeble-minded into a group characterized primarily by intellectual defect, and a second class marked also by deficiencies in neurological and physical equipment. A respect for the principle of multiple causation should lead us to look with favor upon the view that physical-mental relationships vary in nature and degree not only among "classes" but also among individuals.

CHAPTER VII

Physiological Fàctors in Mental Development[1]

NATHAN W. SHOCK

Nutrition

ALTHOUGH BOTH qualitative and quantitative deficiencies in diet are known to have a marked effect upon physical growth and development, the relationship of nutritional factors to mental development is still obscure. On the basis of clinical observation, Zuck (637) is of the opinion that any severe toxemia or dietary disturbance after birth may leave in its wake a deviation from the normal growth pattern which ultimately handicaps the individual in reaching his hereditary expectancy. He places particular emphasis on prenatal disturbances of a nutritional character which he believes have their greatest effect on the nervous system because of the rapidity of neural growth prior to birth. He also believes that postnatal nutritional disturbances are more apt to result in alterations in physical rather than in mental growth. The concept of prenatal nutritional disturbances is difficult to reconcile with numerous animal experiments which tend to show the avidity with which the developing fetus seizes upon necessary foodstuffs even at the expense of the maternal organism.

In a quantitative study of forty boys, ranging in age from three years and eight months to fifteen years and seven months, Poull (623) found an average rise of ten points in IQ when nutrition was improved between the first and second mental tests. The author concluded that the younger the child is at the time nutritional treatment is begun, the greater is the chance of mental improvement. The indication is that a period of eighteen months to two years is required to bring about any appreciable gain from nutritional care. Although the results of this study are suggestive, it must be remembered that mental tests at lower ages are less reliable than at higher, and that in the absence of adequate control, factors other than nutrition may have changed between the two successive tests.

Since adequate studies of the effect of nutrition on mental development in humans are so few it may be well to consider the results of animal experiments. Briefly, little or no effect on maze learning ability has been found in white rats with quantitative restriction in diet (594, 624). This appears to be true irrespective of age at which the deprivation occurs. On the other hand, it has been shown conclusively that vitamin B_1 deficiency reduces maze learning ability in white rats and that the reduction in learning ability is greater if the dietary deficiency is present early in life while the central nervous system is still undergoing growth (592, 593, 615, 616, 617, 620, 621, 622, 625).

[1] Bibliography for this chapter begins on page 137.

The effect of rickets on intellectual development is still an open question. Todd (486, 630) has offered the opinion that rickets as a nutritional disturbance has a deleterious effect on mental development. The observational data upon which this opinion is based have not been published in terms of correlations, group means, or growth curves. Gesell (33) has reported a study made at Yale under the direction of Ullmann, who found only a slight advantage in intelligence scores in non-rachitic children over rachitic children when tested at the ages of twelve to twenty-four months. From this Gesell concluded that the retardational effect of rickets on mental growth is less than is commonly supposed and is transient in character. On the other hand, Brander (595), from an investigation of 375 prematurely born children who were tested when between the ages of seven and fifteen years, reported that the more severe the residual manifestations of rickets the lower was the average value of the IQ. The author believes that both rickets and backward intelligence have the same origin, namely, premature birth; such a position, however, is not in accord with American studies. Brander's investigation was conducted on a group among whom socio-economic factors may have been of considerable importance; there was no evidence that these factors were controlled. We must conclude that the quantitative data necessary for evaluating the effects of rickets on intellectual development are yet to be gathered.

Diabetes and Intelligence

Since the discovery of insulin there has been added to the school population an entirely new group of children, namely, those who are suffering from diabetes and those who have been diabetic over a period of years, even from birth. Thus the question as to the relationship between diabetes and mental development is of increasing importance. White (634) made a detailed study of 169 diabetic children and found an IQ above 110 in 23 percent, from 90 to 100 in 54 percent, and below 90 in 13 percent of the children. Of four diabetic children in whom mental deterioration occurred, definite cerebral trauma was shown to be the causal factor in two. In view of the high incidence of IQ above 110, White concluded that in the period of life in which mental growth was increasing at a rate far exceeding that of the older child, the diabetic had better than average intelligence, proving that diabetes is not a handicap to mental progress. It should be pointed out, however, that all the children studied were under treatment with more or less adequate control of diabetic symptoms. West, Richey, and Eyer (633) administered the Stanford-Binet test to 76 juvenile diabetics and found that the average IQ of the diabetics was somewhat higher than in normal children, although there was considerable variation. Improvement in diabetes did not raise the IQ, and when the diabetic control lapsed the IQ tended to remain unchanged or to rise. Since a socio-economic selective factor may operate when diabetics under treatment are studied and compared

with the average population, the previous studies need a more adequate control of this factor. Such a study has been reported by Brown (597), who compared mental test data of 60 diabetic children with similar test data obtained on 28 siblings of the diabetics. It was found that the group of diabetic children was distributed normally as to intelligence; 23 percent of the diabetics were within the IQ range of 90 to 100 and approximately equal numbers above and below. Both the mean and the median IQ were almost exactly 100 as compared with a median IQ of 106 for the siblings. No relationship was found between duration or severity of the disease on the one hand and intelligence on the other. School achievement and behavior of the diabetic group compared favorably with that of their siblings in spite of poor school attendance. It is suggested that the high percent of bright children in the diabetic group studied by White (634) may be due in part to the high percent of Jewish children among the cases and in part to the selection of the patients from upper socio-economic levels. From these studies it may be concluded that objective evidence of superiority of intelligence of diabetic children is lacking; on the other hand, there is no indication that diabetes leads to mental retardation.

Thyroid Function and Mental Development

Studies of the mental and physical development of cretins have firmly established the role of the thyroid gland in this condition. The importance of early recognition and persistent treatment of thyroid therapy is borne out in numerous studies. Brown (596) found an average IQ of 60 in a group of 32 cretins as compared with an average of 95 for siblings of these patients. He also reported improvement in mental symptoms from thyroid therapy.

Marked individual differences in the degree of mental improvement following thyroid therapy has been found. Gesell, Amatruda, and Culotta (601) made repeated physical and mental examinations in a group of cretinous infants. They found a marked physical improvement in all the cases, although the mental status varied widely from persisting severe mental deficiency in two cases, with normal intelligence in four. Lewis, Samuel, and Galloway (610) interpreted the marked individual differences in the degree of mental improvement produced by thyroid therapy in different cretins in terms of hereditary differences. Gordon and Kuskin (605) were of the opinion that if mental retardation occurs during the first year it is associated with a delay of both physical and mental development. Gordon, Kuskin, and Avin (606) administered thyroid to a group of 155 endocrine cases with mental retardation and found that the best results in the endocrine group occurred with early recognition and early and long-continued treatment. Better results were obtained with individuals who had a higher intelligence level at the first test. Wilkins (635) found that cretins responded to thyroid therapy with rapid osseous development,

less rapid rise in height, rapid loss of torpor, and initial stimulation of activity, followed by a more gradual mental development. In summarizing the clinical and experimental findings, we may say that early recognition and long-continued thyroid therapy will produce some improvement in mental functions in a high proportion of cretins, but that normal intelligence is attained in relatively few cases. This may be due to irreversible changes which have taken place in the central nervous system prior to the beginning of the thyroid therapy, and hence it is possible that with earlier recognition and more persistent treatment a higher proportion of cases with normal mental development may be found.

Pituitary Function and Mental Development

It has been shown both clinically and experimentally that certain types of dwarfs result from disorders of the pituitary gland. However, the relationship between this somatic dwarfism and mental growth is still obscure. Wilkins (636) gave the Otis self-administering intelligence test to 30 dwarf inhabitants of a midget village and found an average IQ of 80. Six individuals who were given the Stanford-Binet intelligence test had an average IQ of 97 with a range of 65 to 116. However, it is impossible to tell whether the apparent mental retardation is a function of the endocrine unbalance or is due to the restricted experiential background of these subjects. Furthermore, no adequate method of diagnosing the origin of the dwarfism in these subjects was available. And since dwarfism may be produced by causes other than pituitary dysfunction, little light is shed on the relationship between mental growth and the pituitary gland.

Clinical reports have appeared in the literature which purport to show improvement in intellect or in intellectual performance in children resulting from the oral administration of desiccated pituitary substance. Konikow (608) administered a mixture of pituitary gland, thymus gland, and thyroid gland with calcium phosphate to a mentally retarded girl of fourteen and found a sudden stimulation in growth with an attendant improvement in her school marks. Renewed intellectual retardation occurred when treatment was discontinued for two months and then improved again with its resumption. Fox (600) was able to show some slight improvement in IQ in mentally retarded children by the administration of thyroid, although she had no success in altering the IQ with oral pituitary administration in sixteen mentally retarded children who had been diagnosed as hypo-pituitary. Mateer (612, 613, 614) reported phenomenal improvement in reading disabilities resulting from pituitary administration. From an analysis of 100 consecutive pituitary deficiency cases old enough to have reading experience, she maintains that no matter how high the intelligence of the patient he is relatively poor in reading.

As is the case in many other clinical reports, educational, environmental, and glandular therapy were always administered simultaneously so that

a scientific evaluation of the results is impossible. In considering clinical reports of the effect of oral pituitary therapy, it is important to remember that in no instance has a physiological effect been observed in animal experiments when the pituitary substance has been administered by mouth. Whatever other disagreements may be found in physiological literature on the pituitary gland, experimenters are practically unanimous in agreeing that all the active principles of the pituitary gland are destroyed in the alimentary tract (598, 599). Thus in evaluating the effect of pituitary medication on intelligence, we are faced with the dilemma of choosing either the rigorously controlled but negative results of animal experiments in the oral administration of pituitary extracts or the optimistic but uncontrolled reports of clinical success in the treatment of intellectual retardation.

Skeletal Maturity

When the degree of ossification of the hand, as observed from X-ray photographs, is used as a measure of physiological maturity, correlations with mental growth and development are usually found to be significant at lower age levels. They tend to disappear with increasing chronological age; for instance, West (632) found coefficients of correlation between percent of ossification and mental test scores of .54 in the first year of the Harvard growth studies in which over 200 girls of north European descent were measured over a twelve-year age range. At that time the average age of the girls was six years and eleven months. By the eighth year of study when the girls were seven to fifteen years of age the correlations dropped to .25 or .35. When the girls were sixteen years and eleven months of age the correlation was only —.03. In a study of 179 boys and 178 girls, aged eight to seventeen, Abernethy (540) found low, insignificant correlations between ossification ratio and scores on the psychological test. Correlations were computed at each age level and for each sex, but none was significant. Neither could a consistent relationship between the amount of gain on the psychological test and the amount of gain in ossification ratio be shown, although increments in the various physical characters were rather closely interrelated. In a study of 800 mentally deficient boys, Flory (555) found that the carpal bones develop at a slower rate and over a longer time and reach a lower maximum size in the mentally retarded than in the average boy in the Laboratory School of the University of Chicago. The ossification ratio of the mentally deficient boys was lower than the ratio for laboratory school boys at all ages. In addition, anomalies in the physical development of mentally deficient boys, as measured by alteration in ossification, appeared to be more numerous and more severe than in the general population. These results led Flory to conclude that the growth rate in physical traits is slower with mentally deficient than with normal boys, and that the rate of growth is related to the degree of mental defect. Both Zuck (637) and Todd (630) have described with considerable assurance the

retarding effect of physical disease and nutritional upsets upon mental development, although objective proof of this relationship is not offered and does not seem to be borne out by controlled observations made elsewhere. Todd regarded X-rays of the hand and knee as sound indexes for detecting and observing the incidence of these physical upsets and for correlating them with signs of mental retardation.

Sex Glands and Sexual Maturity

Although references to the increased intelligence of eunuchs may be found in the literature no evidence of any direct influence of the sex glands on intelligence has been adduced. Molitch and Poliakoff (619) found that among a group of 81 inmates of a New Jersey State Home for Boys, those suffering from hypogonadism, undescended testes, and delayed secondary sex characters, tended to be brighter than the average for the population of the Home as a whole; in fact, only 8 to 27 percent of these boys were of subnormal intelligence as compared to 50 percent of the total Home population. These findings, however, may be due to selective factors related to the type of behavior causing the commitment to the Home. Since eleven of the boys with undescended testes were successfully treated with injections of anterior pituitary-like gonadotropic hormones, it seems that these cases are also pituitary in origin with emphasis on the gonadotropic rather than thyrotropic and growth factors and are not primarily related to the sex glands at all. It should be noted that these children with undescended testes who were the brightest of all the boys with endocrine disorders were, however, the most serious truant and school problems. Treatment of these cases with gonadotropic hormones produced physical improvement but produced no change in intelligence or personality (618).

On the other hand, when age of sexual maturity or puberty is regarded simply as another index of physiological maturation and compared with mental development, interesting results are obtained. When intelligence scores of adults are correlated with reported age of first menstruation, lack of correlation is uniformly reported; for instances Viteles (631) correlated age of pubescence with results from psychological examinations in 236 first-year students between the ages of sixteen to twenty-four years, in a normal school, and found no significant correlation. Similar negative results were reported by Abernethy (540) for data obtained on adults. In a study of 338 college women Stone and Barker (626, 628) found no significant correlations between intelligence test scores and menarcheal ages. These results led to the conclusion that if there is a spurt in development with the advent of puberty those who mature late profit about as much by it as those who mature early, and the effect of such a mental spurt is not seen in adult life. On the contrary, when prepubertal and postpubertal children of the same chronological age are tested, the postpubertal children tend to have slightly higher intelligence test scores than the prepubertal children of the same chronological age. Baldwin (591)

reported that at each chronological age, physiologically accelerated boys and girls have a higher mental age than the physiologically normal or retarded children. This agrees in general with earlier and later studies by other authors. Lutz (611) found that in a mentally superior group of boys, pubescence begins at 12.5 years, in a normal group at 13.5, and in a dull group at 14.5. Terman (629) also reported that the upper percentiles, according to intelligence, attain puberty earlier than the average. Franzblau (557) calculated the correlation between intelligence ratio and age of first menstruation in the various racial groups, and found values ranging from .03 to —.28, in which a maximum correlation of $-.28 \pm .042$ was obtained for her Italian-American group. The partial correlations with age held constant were insignificant for all age groups. When the correlation ratio, etc., was computed, values ranging from $.263 \pm .048$ to $.414 \pm .050$ were obtained. Since the interpretation of the intelligence ratio as computed in this study was difficult, and since no difference in total point score was found between prepubertal and postpubertal subjects at a constant chronological age, the author concluded that no relation exists between intelligence and age at first menstruation. However, in a group of 175 postmenstrual and 175 premenstrual girls, paired for chronological age, Stone and Barker (626) found small but significant differences in scores on the Otis group-intelligence test in favor of the postmenstrual group.

Freeman and Flory (137) studied the mental development of 38 girls who had been tested eight or more times by the University of Chicago VACO tests and from whom data were available as to the time of first menstruation. At each age from nine to sixteen, those maturing before thirteen years showed average scores consistently superior to the average for those maturing at fourteen or after. The differences disappear after age sixteen. Similar results were obtained when mental growth curves were compared for groups classified in terms of a composite measure of physiological maturity—skeletal age based on metatarsal ossification, pubescent maturity, and physical age based on height and weight. In a group of 58 boys, however, no clear-cut differences were found when the boys were classified according to physiological maturity. The writers considered that this may have been due to the small number of cases; it would, however, be equally reasonable to assert that the positive results with the girls may have been due to the small number of cases. Their results showed clearly that the intellectual growth curves of boys and girls do not differ in the same way as their physical growth curves. Abernethy (540) reported a positive correlation between physiological maturity and mental test scores at every age from nine through seventeen for boys and from nine through sixteen for girls. These studies of the relation of the age of pubescence to mental growth suggested that individual differences in the rate of physical maturing exist from earliest childhood and are associated with differences in the rate of mental maturing. In other words, although at maturity differ-

ences disappear, those individuals with a rapid rate of physiological maturity tend to have a correspondingly rapid rate of mental maturity.

If we now consider cases in which physiological maturity has been greatly accelerated, as, for instance, in cases of pubertas praecox, we find that no such corresponding acceleration in mental maturity is present. Stone and Doe-Kuhlmann (627) examined the case histories of 190 cases of pubertas praecox reported in the medical literature but found that in only six cases had a mental test been given. In 62 cases something was said about the mental development of the child, usually quite general in character. From this survey indications were that mental development was seldom accelerated and often retarded in such cases. In a review of 80 more recent cases of pubertas praecox selected from the medical literature, Keene and Stone (607) found that 23 percent were reported as above normal with respect to intelligence or school achievement, 48 percent were reported as normal, and 28 percent were reported as below normal, although only 15 out of this total were given standardized intelligence tests. The available evidence suggests that the mental development does not undergo a spurt in keeping with the body structure in cases of pubertas praecox. A more direct attack on this problem was afforded in the studies reported by Gesell (602, 603, 604), who was able to make annual measurements on three cases of pubertas praecox during the course of development of the disease. The results of these standardized tests showed that precocious displacement of pubescence does not carry with it a coordinate deviation in the cycle of mental growth; in fact, such precocity may apparently alter psychic patterns and introduce affective alterations in the attitude and in the temperamental susceptibility. There may be an increment in social development but there is no corresponding increment in the sphere of mental development. Leiner (609), in a review of the literature, concluded that mental precocity is very rare in pubertas praecox and is found only in the male sex when the pineal is primarily involved.

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Chapter II. Mental and Motor Development from Two to Twelve Years

(See also Nos. 6, 9, 10, 13, 17, 19, 52, 77, 80)

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